FINAL DESIGN ANALYSIS

90312R02
Part 1
2ND COPY

CUTOFF WALLS AND CAP FOR LIME AND M-1 SETTLING BASINS

ROCKY MOUNTAIN ARSENAL
COLORADO

OCTOBER 1990

US Army Corps
of Engineers
Omaha District

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
10/00/90

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
CUTOFF WALLS AND CAP FOR LIME AND M-1 SETTLING BASINS, ROCKY MOUNTAIN ARSENAL, COLORADO — Part I

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ARMY CORPS OF ENGINEERS. OMAHA DISTRICT
OMAHA, NE

8. PERFORMING ORGANIZATION REPORT NUMBER
90312R02

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
ROCKY MOUNTAIN ARSENAL (CO.). PMRMA
COMMERCE CITY, CO

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
THIS DOCUMENT CONSISTS OF 2 PARTS: FINAL DESIGN ANALYSIS, AND SPECIFICATIONS.

DTIC QUALITY INSPECTED 5

14. SUBJECT TERMS
SPECIFICATIONS, DESIGN, CONSTRUCTION, HEALTH AND SAFETY

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

FINAL DESIGN ANALYSIS
FOR

CUTOFF WALLS AND CAP FOR LIME AND M-1 SETTLING BASINS
ROCKY MOUNTAIN ARSENAL, COLORADO

TABLE OF CONTENTS

PART 1 - GENERAL DESCRIPTION

1. **PURPOSE.** The purpose of the project was to develop a design for the Interim Response Actions (IRA) at the Lime and M-1 Settling Basins at Rocky Mountain Arsenal (RMA), Commerce City, Colorado. The purpose of the IRA at the Lime and M-1 Settling Basins is to mitigate the threat of release from the Basins on an interim basis, pending determination of the final remedy in the Onpost Record of Decision (ROD). The IRA for the M-1 Basins also includes treatment of the waste materials in the basins with in-situ vitrification (ISV), which is being designed by contract with Woodward-Clyde Consultants.

2. **AUTHORIZATION.**

2.1 **AUTHORITY.** This project was authorized by DD Form 448 from Program Manager for Rocky Mountain Arsenal.

2.2 **DECISION DOCUMENTS.** Based on RMA's evaluation of the proposed alternatives, the Decision Documents were determined as shown in appendix C. The IRA for the Lime Settling Basins consists of relocation of sludge material, which has been deposited around the Lime Settling Basins, to the Lime Settling Basins area; construction of a 360-degree subsurface barrier around the basins; construction of a soil and vegetative cover over the material; and installation of a ground-water extraction system. The IRA for the M-1 Settling Basins consists of construction of a temporary 360-degree subsurface barrier such as a slurry wall or sheet pilings around the M-1 Settling Basins area, and the treatment of the waste materials in the basins with in-situ vitrification.

3. **CRITERIA.** Criteria used in the remedial design are referenced in Part 2 of this report, and are based on applicable local, state, and federal regulations.

4. **PROJECT DESCRIPTION.** The following is the project description as quoted from applicable portions of the Decision Documents for the Lime Settling Basins and M-1 Settling Basins at Rocky Mountain Arsenal.

4.1. **SITE NAME, LOCATION AND DESCRIPTION.**

4.1.1. **LIME SETTLING BASINS.** The Lime Settling Basins are located north of the South Plants area, just north of December 7th Avenue along the southern edge of the southwest quarter of section 36. The Lime Settling Basins occupy about 5 acres. For the purpose of the alternatives assessment, it was estimated that approximately 80,000 cubic yards of sludge within the basins, plus approximately 26,000 cubic yards of sludge that had been placed adjacent to the basins for drying, would be addressed by the IRA.

4.1.2. **M-1 SETTLING BASINS.** The M-1 Settling Basins are located in the South Plants area, just south of December 7th Avenue along the northern edge of the northwest quarter of Section 1. The basins and the berms surrounding them, all of which are now buried and partially built upon, occupy an area of approximately 34,500 square feet. For the purpose of the alternatives assessment it was estimated that approximately 6,400 cubic yards of sludge plus 2,600 cubic yards of overburden would be addressed by the IRA.

4.2. SITE HISTORY.

4.2.1. LIME SETTLING BASINS.

4.2.1.1. During the 1940's and 1950's, wastewater from the production of Army agents was routinely treated prior to discharge to unlined evaporation ponds. This treatment involved the addition of lime to the wastewater to precipitate metals and reduce the arsenic concentration. Wastewaters produced in the South Plants were channeled through the Lime Settling Basins prior to gravity discharge to Basin A, just to the north. The precipitation process produced a lime sludge that contained elevated levels of heavy metals, arsenic, and mercury. Subsequent discharges of pesticide production wastewater resulted in the addition of pesticide to the Lime Settling Basins sludge. The Lime Settling Basins were taken out of service in 1957.

4.2.1.2. A number of studies have been completed to characterize the nature and extent of contamination in the soil, sludge, and ground-water in the vicinity of the Lime Settling Basins. These studies are referenced in the Decision Document and the results are consistent with the site history. The soil and sludge contain elevated levels of organochlorine pesticides, organosulfur compounds, arsenic, mercury, and ICP metals (cadmium, chromium, copper, lead, and zinc).

4.2.2. M-1 SETTLING BASINS.

4.2.2.1. The M-1 Settling Basins were constructed to treat fluids form the lewisite facility. Two basins were constructed in 1942, and a third was constructed in 1943 when the original two filled with solids. All three were unlined, and each measured approximately 90 feet wide, 115 feet long, and 7 feet deep. In addition to the waste fluids from the lewisite disposal facility, the basins may have contained lesser amounts of waste materials from alleged spills within the acetylene generation building, the thionyl chloride plant, and the arsenic trichloride plant, which may have been routed through floor drains and the connecting piping to the basins. The basins also received a considerable amount of mercury chloride catalyst, possibly from a spill.

4.2.2.2. The liquids discharged into the basins first passed through a set of reactor towers where calcium carbonate was added, then through a wood trough into the M-1 Settling Basins where the arsenic precipitated out of solution. The liquid from the settling basins was decanted through an 18 inch diameter pipe to the Lime Settling Basins where final treatment occurred, before being routed to Basin A. The M-1 Settling Basins were backfilled, probably in 1947, and are now covered with soil. Portions of the basins are covered with structures. These structures will be relocated as part of this IRA before implementation of the ISV treatment.

4.2.2.3. Based on several investigations, the contaminants in the waste material in the M-1 Settling Basins are primarily arsenic (about 8 percent) and mercury (about 0.5 percent), with the bulk of the material being oxides or carbonated of calcium. Organochlorine pesticides and other organics have also been found in the near-surface soils. The bottoms of the basins appear to be about 7 feet below ground surface, based on as-built drawings and field investigations.

PART 2 - DESIGN REQUIREMENTS AND PROVISIONS

1. GEOLOGY.

1.1 GENERAL GEOLOGY.

1.1.1 Physiography. The Rocky Mountain Arsenal (RMA) lies within the Colorado Piedmont section of the Great Plains physiographic province. This area is characterized by surface deposits of wind-blown and alluvial materials. The Arsenal lies near the eastern edge of the valley along the South Platte River. The topography of the Rocky Mountain Arsenal area consists of gently rolling hills with occasional prominent hills which contain bedrock outcrops.

1.1.2 Description of Overburden. Overburden in the Rocky Mountain Arsenal area consists of both alluvial and eolian deposits of silts, clays, sands, gravels and a few cobbles.

1.1.2.1 There are several distinct deposits that make up the overburden that have been identified in the Rocky Mountain Arsenal area. The Quaternary units, from oldest to youngest, include the Verdos, Slocum, Louviers, Broadway, unnamed loess, unnamed eolian, Piney Creek, and Post Piney Creek. The older alluvium is primarily coarse-grained sands and gravels whereas the younger alluvium and the eolian deposits are primarily finer grained materials. The alluvial materials were deposited in irregular, braided channel environments creating typical lenticular deposits. The eolian materials are generally silts and fine sands. The thickness of these deposits in the vicinity of the Rocky Mountain Arsenal varies from 130 feet thick to less than 20 feet. These materials are generally unconsolidated and lie unconformably on the Cretaceous-Tertiary Denver Formation.

1.1.3 Bedrock Stratigraphy. The bedrock unit lying directly below the Quaternary alluvium is the Denver Formation. Immediately underlying the Denver Formation is the Arapahoe Formation. The thickness of the Denver Formation in the vicinity of the Rocky Mountain Arsenal varies from 200 to 500 feet. The Denver Formation was derived from the erosion of basaltic and aesthetic material and was deposited by fluvial processes. The Denver Formation consists of units of interbedded siltstones, claystones, sandstones and lignite. A low permeability volcaniclastic layer is present in the upper portion of the Denver Formation. This volcaniclastic layer contains lithic fragments and minerals in a bentonitic clay matrix which probably is the product of a weathered volcanic ash deposit. Sandstone layers of the Denver Formation are usually discontinuous, lense-shaped and generally grade laterally and vertically into shales and siltstones. The lignite layers are more continuous than the sandstone layers and are usually fractured.

1.1.4 Bedrock Structure. The Rocky Mountain Arsenal facility lies in the northwestern portion of the Denver Basin. The Denver Basin is an extensive, oval-shaped, structural depression extending from eastern Colorado and eastern Wyoming into western Kansas and western Nebraska. The sedimentary rocks that fill the Denver Basin are predominantly shales, sandstones, conglomerates and occasionally some limestones. The gently dipping slope of

shallow bedrock formations of the Denver Basin is one degree or less in the vicinity of the Rocky Mountain Arsenal and is predominantly to the southeast.

1.2 INVESTIGATIONS SUMMARY.

1.2.1 General. Pre-design investigations consisted of review of IR and IRA reports and field investigations of both the Lime and M-1 Basin areas. The field investigations included topographic surveys , drilling, sampling, and permeability testing for geotechnical and chemical testing. Corps personnel visited the Arsenal to observe, photograph, and quality check the Contractor.

1.2.2 Topographic Surveys. In order to develop existing site conditions, a topographical survey was conducted to establish horizontal and vertical control. Subsequent mapping was prepared. The mapping, which contains all topographic features, was drawn at 1"=50' for the Lime Basins Area, and at 1"=20' for the M-1 area. A 1 foot contour interval was used. The survey was also used to determine the field locations of the Lime Settling and M-1 Basins. Since the M-1 Basins are buried, stakes were placed at the boundaries. The locations were determined from as-built drawings and reviewing aerial photography.

1.2.3 Exploration Drilling for Lime Settling Basins.

1.2.3.1 Equipment and Personnel.

1.2.3.2 Boring Locations and Purpose.

1.2.3.3 Slug Tests.

1.2.3.4 Backfilling Holes.

1.2.4 Exploration Drilling for M-1 Basins.

1.2.4.1 Equipment and Personnel.

1.2.4.2 Boring Locations and Purpose.

1.2.4.3 Backfilling Holes.

1.3 SITE GEOLOGY.

1.3.1 Lime Settling Basins.

1.3.1.1 Bedrock. Bedrock beneath the Lime Settling Basins area is the Cretaceous-Tertiary Denver Formation. The unconformable contact between the bedrock and the overlying surficial deposits is irregular due to erosion of the surface of the bedrock prior to the deposition of the surficial material. The uppermost portions of the Denver Formation are weathered and often fractured.

1.3.1.1.1 Lithology. The Denver Formation in the vicinity of the Lime Settling Basins consists of claystone and sandstone. The claystone

CUTOFF WALLS AND CAP FOR LIME AND M-1 SETTLING BASINS ROCKY MOUNTAIN ARSENAL, COLORADO

Changes for the 90% Design Analysis, dated October 1990: See page 2-2, delete paragraph 1.2 in its entirety and substitute the following.

1.2 INVESTIGATIONS SUMMARY.

1.2.1 General. Pre-design investigations consisted of review of IR and IRA reports and field investigations of both the Lime Settling Basins and M-1 Basin areas. The field investigations included topographic surveys, drilling, and sampling, for geotechnical and chemical testing and in-situ permeability testing. Topographic surveys were conducted by Government personnel. Drilling, sampling and permeability testing was accomplished under contract with Woodward Clyde Consultants (WCC). Omaha District personnel visited the work site to oversee the work of the contractor. The discussion of the drilling, sampling, and permeability testing is a summary of the work done by WCC. A complete discussion of the field investigations performed by WCC is included in their report "Field Investigation, Lime and M-1 Settling Basins Slurry Walls, Rocky Mountain Arsenal, Commerce City, Colorado" dated September, 1990, Volumes I and II.

1.2.2 Topographic Surveys. In order to develop existing site conditions, a topographical survey was conducted to establish horizontal and vertical control. Subsequent mapping was prepared. The mapping, which contains all topographic features, was drawn at 1"=50' for the Lime Basins Area, and at 1"=20' for the M-1 area. A 1 foot contour interval was used. The survey was also used to determine the field locations of the Lime Settling and M-1 Basins. Since the M-1 Basins are buried, stakes were placed at the boundaries. The locations were determined from as-built drawings and reviewing aerial photography.

1.2.3 Exploration Drilling for Lime Settling Basins. Field investigations for the Lime Settling Basins were conducted by WCC during June and July 1990. Field investigations consisted of electro-magnetic surveys for locating buried metallic objects, exploratory drilling, slug tests for hydraulic conductivity analysis, ground-water sampling, soil sampling and analyses, and bulk sampling for compatibility testing and borrow area analysis. All drilling except the borrow investigations was conducted in level B protection.

1.2.3.1 Equipment and Personnel. Drilling was accomplished by Layne-Western Co. under contract to WCC. Drilling and sampling was accomplished by drilling with 6 1/4-inch OD hollow stem augers using a CME 75 or CME 750 drilling rig. The majority of samples were obtained by a 3-inch OD, stainless steel split spoon driven by a 140-pound hammer. Continuous auger cores were taken of bedrock in polybutyrate tubes. Logging and sampling of borings were done by WCC personnel.

1.2.3.2 Boring Locations and Purpose. A total of 30 borings were drilled for the investigation of the Lime Settling Basins Project. Nineteen borings were drilled along the alignment of the slurry trench to identify the subsurface materials and to determine the consistency density and moisture content of the overburden, and the nature and characteristics of bedrock including degree of weathering, fracturing, and cementation, and relative hardness. Eight borings were drilled outside the slurry trench area to determine the extent of waste material that hand been removed from the Lime Settling Basins. Three wells were installed inside the slurry trench area for slug tests to determine the hydraulic conductivity of the overburden aquifer. Samples were taken from all borings for geotechnical analyses; compatibility testing; and chemical analyses.

1.2.3.3 Slug Tests. Slug tests were conducted in wells installed in borings LSB-15, LSB-34, and LSB-35 on 24 and 25 July 1990. These slug tests were conducted to ascertain the hydraulic conductivity of the overburden aquifer within the isolation cell, particularly for the design of the ground-water extraction system. The wells were constructed of 4-inch ID PVC riser pipe and 10 feet of slotted PVC casing used for the well screen. The bottom of the screens were placed at the top of bedrock. The screens were sand packed to the top of the aquifer then sealed with hydrated bentonite pellets and bentonite grout to the ground surface. The wells were developed with a 3-inch diameter steel surge block. After development the wells were allowed to recover two weeks before initiation of the slug tests. Slug tests were conducted using an automated data logger, 10-psi range pressure transducer probe, and a 5-foot long slug constructed of PCV pipe filled with sand and capped at each end. A falling head slug test and a rising head slug test were conducted in each well. The tests were continued until 90 percent of the induced head change was dissipated. Data and analysis of the slug tests are included in appendix A.

1.2.3.4 Backfilling Holes. All holes were backfilled with grout after completion.

1.2.4 Exploration Drilling for M-1 Basins. Field investigations were also conducted in July 1990. With the exception of slug tests, field investigations were identical to those conducted at the Lime Settling Basins.

1.2.4.1 Equipment and Personnel. Equipment and personnel involved in field investigations for the M-1 Basins were essentially the same as those at the Lime Settling Basins.

1.2.4.2 Boring Locations and Purpose. A total of 29 borings were drilled for the investigation of the M-1 Basins. Of these 12 were drilled for the design of the sheet pile wall, 2 were drilled for background geological information, and 15 were drilled within the basins to obtain data for the design of the in-situ soil vitrification project, primarily to characterize the waste sludge. As for the Lime Settling basins borings, borings drilled along the alignment of the sheet pile wall were drilled to determine the nature and character of the overburden and bedrock materials.

1.2.4.3 Backfilling Holes. All exploratory borings were backfilled with grout after completion.

is generally soft to moderately hard, brown, and blocky and is occasionally silty. Sandstone lenses are also frequently encountered. The sandstone units are fine-grained and vary from soft to hard, depending upon the degree of cementation and weathering, and fine grained. These sandstones also contain silt, thus making them less pervious. A thick, up to 15 feet, fine-grained sandstone lense occurs in the northern section of the isolation cell.

1.3.1.1.2 Bedrock Topography and Structure. The Denver Formation bedrock lies at depths of 13.5 to 27.5 feet below the surface in the Lime Settling Basins area. The local slope of the surface of the bedrock is very gentle, about two degrees, to the north-northeast. It also displays paleochannel valleys and benches. This type of paleotopography is due to stream erosion. The dip of the Denver Formation has not been determined, but it is probably the same as the regional dip, about one degree or less to the southeast. A bedrock contour map is included in Appendix A.

1.3.1.2 Overburden. The overburden in the Lime Settling Basins area is of Quaternary age and is the result of deposition by the ancient Platte River drainage network and eolian processes.

1.3.1.2.1 Lithology. The thickness of the overburden ranges between 13.5 and 27.5 feet in the Lime Settling Basins area. The soils consist mostly of poorly graded, silty, fine-grained sand with moderate amounts of sandy, silty clay and minor amounts of clayey sand, sandy clay, silty clay, and clay. The sand ranges from loose to dense and the clay ranges from soft to very stiff. The overburden soil ranges from dry to saturated with moisture content increasing with depth.

1.3.1.2.2 Alluvial Aquifer Material. The aquifer material is generally unconsolidated, fine-grained sand or silty, fine-grained sand, and clayey fine-grained sand overlying the top of bedrock. The saturated thickness ranges from 9.5 to 21.0 feet.

1.3.2 M-1 Basins.

1.3.2.1 Bedrock. The bedrock beneath the M-1 Settling Basins area is the Cretaceous-Tertiary Denver Formation. The unconformable contact between the bedrock and the overlying surficial deposits is irregular due to erosion of bedrock prior to the deposition of the surficial material. The uppermost portions of bedrock are weathered and often fractured.

1.3.2.1.1 Lithology. The upper portion of the bedrock is weathered, soft to moderately hard, dark brown claystone occasionally interbedded with moderately hard to hard, fine-grained sandstone and sandy siltstone.

1.3.2.1.2 Bedrock Topography and Structure. The Denver Formation bedrock is located at depths of 9.0 to 14.5 feet below the surface in the M-1 Settling Basins area. The slope of the surface of the bedrock is very gentle, less than one degree to the north. The bedrock surface was shaped by stream erosion. As at the Lime Settling Basins, the dip of the Denver Formation probably coincides with the regional dip of one degree or less to the southeast.

1.3.2.2 Overburden. The overburden material in the M-1 Settling Basins area is of Quaternary age and is the result of deposition by the ancient Platte River drainage network and eolian processes.

1.3.2.2.1 Lithology. The overburden in the M-1 Basins area is 9.0 to 14.5 feet in thick. The material consists mostly of unconsolidated, fine-grained, yellowish to grayish brown sand and silty sand with silt and clay of alluvial or eolian origin; surficial fill material; and chemical waste sludge. The fill extends from the ground surface downward, ranges from 2 to 11 feet thick and consists mostly of a mixture of clay, sand, and gravel occasionally mixed with sandstone and claystone. The chemical waste sludge ranges from 3.0 to 6.5 feet thick. Overburden ranges from dry to saturated with moisture content increasing with depth.

1.3.2.2.2 Aquifer Material. The aquifer material in the M-1 Basins consists of alluvial and eolian materials which are unconsolidated, poorly graded, fine grained sand and occasional silt. Saturated thickness ranges from 3.0 to 4.5 feet.

1.4 HYDROLOGY.

1.4.1 Regional Hydrology. The Rocky Mountain Arsenal lies within the drainage basin of the South Platte River. The South Platte River is approximately 3 miles west and northwest of the Arsenal. Ground-water flow in the Arsenal area is from southeast to northwest eventually discharging into the South Platte River. Ground water in the overburden is generally unconfined while ground-water in the bedrock units is confined. Ground water is unconfined where permeable bedrock units are exposed at the surface or in contact with the overburden. The aquifer units of greatest concern in the Rocky Mountain Arsenal vicinity are in the surficial Quaternary overburden deposits and permeable sandstones of the underlying Denver Formation. The bottom portion of the Denver Formation is a "buffer zone" of shale. This buffer zone is approximately 75 to 200 feet thick and acts as an aquitard between the Denver Formation and the lower bedrock formations of Arapahoe, Laramie Formation, Fox Hills Sandstone and the Pierre Shale.

1.4.1.1 Bedrock. Confined aquifers in the Denver Formation exist in the more permeable sandstones and lignite beds. These beds are separated from the overlying alluvial aquifer by shale or claystone. The Arapahoe Formation underlies the Arsenal area at a depth of 200 to 500 feet below the ground surface. Due to high-volume ground water withdrawals from the Arapahoe Formation over the past 100 years, the vertical gradient between the Denver and Arapahoe Formations in the vicinity of the Rocky Mountain Arsenal has changed from upward to downward. Recharge of the bedrock aquifers occurs from vertical leakage from the alluvial aquifers.

1.4.1.2 Overburden. Unconfined ground-water occurs in unconsolidated surficial alluvium or eolian deposits of sand. Ground-water flow in the alluvium is most rapid through coarse materials found in paleochannels, however, flow does occur throughout the saturated thickness of the overburden deposits. Thick, saturated alluvial deposits are capable of yielding large volumes of water.

1.4.2 Site Hydrology.

1.4.2.1 Lime Settling Basins.

1.4.2.1.1 Bedrock. The Denver Formation is saturated below the Lime Settling Basins and contains some confined aquifers. The most conductive units are generally subhorizontal layers of sandstones and siltstones confined by less permeable claystones. The ground-water flow in the bedrock aquifers is believed to be due north.

1.4.2.1.1.1 Hydraulic Analysis. Hydraulic conductivities for the Denver Formation aquifers vary both vertically and horizontally based on lithology and the degree of weathering and fracturing. Shales and claystones have a reported hydraulic conductivity ranging from 3.53×10^{-6} to 3.53×10^{-8} cm/sec. Unfractured claystones may be as low as 3.53×10^{-12} cm/sec (Stollar and Assoc. 1989). A conservative value of 1.0×10^{-8} cm/sec for the vertical hydraulic conductivity for the claystone was used in calculations for this project. The hydraulic conductivities of the various sandstones have been reported to range from 1.06×10^{-5} to 1.41×10^{-3} cm/sec (Stollar and Assoc. 1989).

1.4.2.1.2 Overburden. The Lime Settling Basins are situated in a local topographic low area. The Lime Settling Basins are hydrogeologically downgradient from the M-1 Settling Basins and the South Plants area. The ground-water flow direction is about due north with a gradient of 0.023 ft/ft. There is ponded water inside the lime settling basins and it has been determined that the ponded water reflects the water table.

1.4.2.1.2.1 Hydraulic Analysis. Slug tests were conducted to determine the hydraulic conductivity for the fine-grained materials in the overburden at the Lime Settling Basins. Three slug tests were conducted, with one test conducted near the center of the isolation cell and the other two conducted 100 feet south of the north wall of the isolation cell. The hydraulic conductivity near the center of the isolation cell was determined to be 2.0×10^{-3} cm/sec. The two tests 100 feet south of the north wall indicated hydraulic conductivities of 1.0×10^{-4} cm/sec and 2.0×10^{-4} cm/sec. In order to perform conservative analyses for the design of the project the lowest hydraulic conductivity was used in all calculations. Review of boring logs and mechanical analyses of samples obtained during the exploration program support the use of the smallest value obtained from the slug tests. Data and analysis of the slug test are included in Appendix A.

1.4.2.2 M-1 Basins.

1.4.2.2.1 Bedrock. The Denver Formation is saturated below the M-1 Basins and may contain some confined aquifers. Subhorizontal layers of sandstones and siltstones, confined by less permeable claystones, are generally the most permeable units of the Denver Formation. Ground-water flow within these aquifer units is generally due north.

1.4.2.2.1.1 Hydraulic Analysis. The aquifers within the Denver Formation have hydraulic conductivities that vary both vertically and horizontally based on lithology. The claystones and shales have reported hydraulic conductivities ranging from 3.53×10^{-6} to 3.53×10^{-8} cm/sec. The sandstones have a reported hydraulic conductivity ranging from 1.06×10^{-5} to 1.41×10^{-3} cm/sec. The uppermost unit of the Denver Formation below the M-1 Basins is claystone.

1.4.2.2.2 Overburden. Paleotopographic influences and localized mounding of ground-water direct the flow of ground-water in the M-1 Basins area due north to slightly northwest. The ground-water gradient ranges from 0.008 to 0.011 ft/ft. The water table varies seasonally between 5 and 10 feet below ground surface. Current water levels range from 7.8 to 10.0 feet below ground surface. The thickness of the saturated zone ranges from about 3.0 to 4.5 feet.

1.4.2.2.2.1 Hydraulic Analysis. The hydraulic conductivities for the overburden aquifer has been reported as ranging from 6.0×10^{-3} cm/sec to 2.4×10^{-3} cm/sec.

1.5 CONTAMINATION.

1.5.1 Lime Settling Basins.

1.5.1.1 Soils. Soil contamination at the Lime Settling Basins has been investigated previously. Contaminants detected have included raw materials, such as mustard agent-related compounds, manufacturing by-products, such as volatile aromatic solvents, and degradation products from the synthesis of insecticides. Previous borings indicate detectable concentrations of organochlorine pesticides (OCP's). The following OCP's were detected: dieldrin, with concentrations from 0.6 to 70 μg/g, aldrin, with concentrations up to 600 μg/g, endrin, with concentrations up to 200 μg/g, and isodrin, with concentrations up to 300 μg/g. Other contaminants found were organosulphur compounds of chlorophenylmethyl sulfide, chlorophenylmethyl sulfoxide, and chlorophenylmethyl sulfone with concentrations up to 50 μg/g. DDT was also found in an isolated area with a concentration of 7 μg/g. Volatile organic compounds (VOC's) were detected in some of the previous deeper borings. Chloroform was detected at concentrations ranging from 2 to 7 μg/g. Benzene was detected at concentrations ranging from 5 to 6 μg/g and chlorobenzene was detected at a concentration of 2 μg/g. The most prevalent metals were arsenic and mercury. Arsenic concentrations were detected as high as 370 μg/g. Mercury was detected at concentrations of 0.159 μg/g. Elevated concentrations of copper, lead, zinc, cadmium, and chromium were also detected. Tetrachloroethene was also detected at a concentration of 0.25 μg/g.

1.5.1.2 Ground Water. Ground-water contaminants in the alluvial aquifer have been detected at the Lime Settling Basins site during previous investigations. These contaminants include VOC's (volatile organic compounds), aromatics, metals, and OCP's (organochlorine pesticides). High concentrations of various VOC's were detected. Arsenic, mercury, chromium, and copper were metals that were detected from previous monitoring well samples.

1.5.2 M-1 Basins.

1.5.2.1 Soils. High concentrations of arsenic and mercury were found in and around the M-1 Basins from depths of 0.5 to 7.0 feet. The concentrations within the basins ranged from 0.01% to 11%. These concentrations generally decreased below the 7-foot depth. Dieldrin, DCPP and BCHPD have also been reported in significant concentrations.

1.5.2.2 Ground water. Previous investigations indicate high concentrations of arsenic and mercury are present in the ground water downgradient of the M-1 Settling Basins.

2. SLURRY TRENCH CUTOFF WALL (LIME SETTLING BASINS).

2.1 Criteria. The Decision Document for the Lime Settling Basins requires the containment system consist of a 360 degree subsurface barrier, vegative cover, ground-water removal system to maintain a negative head in the isolation cell, evaluation of ground-water diversion, and evaluation of potential contamination of bedrock aquifers.

2.2 References. The following references were used during the design process:

EPA-540/2-84-001, Slurry Trench Construction for Pollution Migration Control.

EPA 600/2-87-063, Investigation of Slurry Wall Design and Construction Methods for Containment of Hazardous Waste.

Millet and Perez, "Current USA Practice: Slurry Wall Specifications", ASCE Journal of Geotechnical Engineering, August 1981.

D'Appolonia, "Soil-Bentonite Slurry Trench Cutoffs", ASCE Journal of Geotechnical Engineering, April 1980.

ASTM STP 874, Hydraulic Barriers in Soil and Rock, 1985.

Xanthakos, Slurry Walls, 1979.

Zappi, Shafer, and Adrian, "Compatibility of Soil- Bentonite Slurry Wall Backfill Mixtures With Contaminated Ground-water", Proceedings of Superfund '89 Conference, HMCRI, November 27-29, 1989.

Schulze, Barvenik, and Ayres, "Design of Soil-Bentonite Backfill Mix for the First Environmental Protection Agency Superfund Cutoff Wall".

API RP 13B-1, API Recommended Practice: Standard Procedure for Testing Drilling Fluids.

API Spec. 13A, API Specification for Oil Well Drilling Fluid Materials.

Plans and Specifications, Helen Kramer Landfill Superfund Site, Mantua Township, New Jersey, prepared by the Kansas City District

Plans and Specifications, Kane and Lombard Superfund Site, East Baltimore, Maryland, prepared by EA Engineering Science and Technology Inc.

2.3 Compatibility Study. The presence of chemical contaminants in soil and/or ground-water may significantly alter the rate of water movement through a soil medium. The purpose of compatibility testing is to find the mixture of backfill soil, bentonite, and tap water which will produce the lowest permeability of contaminated ground water over time. The Missouri River Division

(MRD) Laboratory in Omaha will perform the compatibility studies. The lab test request is included in Appendix A. The original request is dated 23 August 1990. On 1 October 1990, MRD lab personnel proposed changes in the testing procedure based on preliminary results of a similar compatibility study presently being conducted for the Forest Waste Superfund Site. The updated test request (dated 10 October) reflects the changes. The updated procedure is described here. After selection of a bentonite source using the free swell and filter cake compatibility tests, optimization testing (one or two-day fixed wall permeability tests) determines the most economical combination of bentonite, backfill soil, and water which yields a permeability of 1 x 10^{-7} cm/sec or less. That combination is used in permeameter tests utilizing both contaminated ground-water and tap water.

2.3.1 Bentonite Sources. Several drillers supply companies in Colorado and two out-of-state companies were contacted to identify potential bentonite suppliers and to obtain samples for conducting compatibility studies. Samples from the following companies were sent to the MRD Laboratory:

Golden Drilling Fluids and Supplies Inc.
Golden, CO
Regular

Dean Bennett Supply Company
Denver, CO
Mudgel

H & H Bentonite and Mud Inc.
Grand Junction, CO
BH-Natural and AS 85

Black Hills Bentonite Company
Palatane, IL
S-5 Natural

Wyo-Ben Inc.
Billings, MT
Hydrogel

The free swell test (EPA Report Number PB 87-229688) and filter cake compatibility test will be used to select the bentonite for this project. Two free swell tests will be performed for each bentonite sample; one using contaminated ground-water and one using RMA tap water (see following paragraph). The bentonite which exhibits the least amount of variation between the tap water and contaminated ground-water test will be selected for the backfill mixtures.

2.3.1.1 Natural vs. Treated Bentonite. The Corps slurry trench guide spec (several years old) specifies natural bentonite only. However, many slurry trench references (EPA-540/2-84-001, Millet and Perez, D'Appolonia, Xanthakos) say that practically all commercially available bentonite contains chemical additives; it is more a matter of how much is added. A memo from Geo-Con Inc., the Kane and Lombard contractor (included in Appendix A) states that most slurry trench specifications allow treated bentonites which conform to API

Spec 13A Section 4 to be used. On the Kane and Lombard project only natural bentonite which conforms to API Spec 13A Section 5 (a new section) was allowed. Geo-Con experienced some problems during construction that they attribute to the natural bentonite. He recommends not using API 13A Section 5 natural bentonites for slurry trenches. Due to time constraints in both this project and the Forest Waste project it was decided to stick with the Corps spec and use only natural bentonites. In the future when time becomes available the MRD lab may do some comparisons between natural and treated bentonites to address this question. Of the bentonites sent to the MRD lab, only 2 (H & H Bentonite's BH-Natural and Black Hill's S-5 Natural are API 13A Section 5 natural and only those two will be used for testing.

2.3.2 Water Samples. To simulate field conditions at the Arsenal site, samples of tap water and contaminated ground water were collected during the pre-design field investigations. Tap water will be used to mix the slurry and backfill materials and ground water will be used as a permanent.

2.3.3 Backfill Soil Samples. Two backfill soils will be tested; the soil to be excavated from the trench and soil from an uncontaminated borrow area on the arsenal. Soil from the trench alignment has been collected as part of the pre-design field investigations. After screening for Army agents, samples from the borings located on the northern half of the slurry trench cell were composited and tested for grain size distribution, Atterberg limits, and water content at the Arsenal. This soil was sent to the MRD Lab for compatibility studies. Prior to the pre-design field investigations it was decided to use soil from the northern boundaries of the trench for compatability studies. This is because the groundwater flow in the area is toward the north and the highest levels of contamination found in the previous studies is to the north of the Lime Basins; therefore that soil should provide the "worst case" testing condition. The boring logs along the trench alignment are very consistent: fill or sludge overlying SM (USCS classification), overlying CL-CH, overlying claystone. The mechanical analyses of the composited samples are also very similar, containing between 17 and 40 percent fines. Due to the overall consistency and the desire to use mostly soil from the northern boundaries while also assuring representative samples, it was decided to thoroughly mix samples from the following borings into one composite: 9, 10, 17, 22, 23, 24, 25 and 26. This represent all borings along the northwest, north, and northeast boundaries of the isolation cell.

2.3.3.1 Borrow Materials. Corps personnel decided to use a clay borrow area used in the remediation of Basin F. Four test pits were excavated in this area. Approximately 150 pounds of soil was collected and sent to the MRD Lab. As there is a limited amount of this material available, this soil will be used as a possible source of fines only and not the primary borrow material. This material classifies as CL, with a liquid limit of 34.6, plastic limit of 13.5, plasticity index of 21.1, and 69.9% finer than the No. 200 sieve. (Laboratory classification data received to date are in Appendix A). Stockpiles of soil excavated from the spillway construction at the Lower Derby Dam on the Arsenal will be used as the primary alternate borrow. Samples of this material were brought to the MRD lab on August 31, 1990 and will be tested for grain size distribution, Atterberg limits and moisture content prior to optimization testing.

2.3.3.2 Chemical Screening of Borrow. Prior to compatibility studies, both borrow soils will be tested for TCLP (Toxicity Characteristics Leaching Procedure), TOC (Total Organic Carbon), sodium, calcium, magnesium, potassium, pH, and cation exchange capacity.

2.3.4 Sample Preparation. The backfill soil samples will be oven-dried at 65 degrees Celsius for 2 to 4 days. The soils will then be broken up, thoroughly mixed, and passed through a U.S. Standard Sieve No. 4. The RMA tap water shall be added to the dried and mixed samples until the original field water content is reached. These reconditioned composite samples shall then be stored for 3 to 6 days in sealed containers at room temperature. During this storage period the samples will be mixed daily.

2.3.4.1 The bentonite slurry shall be prepared by mixing the RMA tap water with the previously selected bentonite source. The slurry shall be mixed with enough water to pass through a Marsh funnel in 40 to 50 seconds. The slurry shall be tested for density, water content, pH, viscosity, and fluid loss.

2.3.5 Optimization Testing. Short-term (1 or 2 days) permeability tests will be performed to determine the most economical combination of bentonite, water, fines and coarse grained soil with a permeability of 1×10^{-7} cm/sec or less. Since tap water and backfill soil are available on the Arsenal, it is anticipated bentonite will be the highest cost item.

2.3.5.1 Three samples (two specimens each) of the insitu slurry trench soil will be prepared containing 0, 2, and 4 percent dry bentonite by weight. Bentonite slurry with a viscosity of 40 seconds (Marsh funnel) will be added to each sample to obtain an approximate 5 inch slump. Fixed wall permeability tests will be run on the 6 specimens. "Total Percent Bentonite vs. Permeability" will be plotted. If permeability values are not less than or equal to 1 x 10EE-7 cm/sec, the above procedure will be repeated with the addition of enough clay borrow soil to make the fines content approximately 10 percent higher than the original insitu composite. If those permeability values are not less than or equal to 1 x 10EE-7 cm/sec, the procedure will be repeated with the addition of clay borrow soil to make the fines content approximately 20 percent higher than the original insitu composite. If permeability values are still too high, the procedure will be repeated with the addition of clay borrow to make the fines content approximately 30 percent higher than the original insitu composite.

2.3.5.2 The optimization testing procedure will also be performed using the random fill borrow soil in place of the insitu soil. Due to the presence of contaminants in the insitu soil there is a possibility that none of the mixtures of insitu soil, fines and bentonite will produce a permeability on the order of magnitude of 10EE-7 cm/sec. If this happens and a mixture of random fill, fines, and bentonite produces an acceptable permeability then only random fill borrow will be used for construction, and long-term permeability tests will be performed using only random fill borrow as the principal soil constituent. If the desired permeability is obtained by mixtures including both insitu soil and random fill borrow then long-term permeability tests will be performed using

both principal soil constituents, and the decision of which soil to use for construction will be made based on the results of those tests.

2.3.6 Permeameter Sample Preparation. Samples for long-term permeability tests will be prepared according to subparagraph 2.3.4, Sample Preparation. The backfill mixtures shall be stored in sealed containers at room temperature until loading into the permeameters for permeability testing. Atterberg limits, fines content, porosity, density, water content, specific gravity, cation exchange capacity, and pH of the backfill mixtures will be determined. Before the backfill materials are loaded into the permeameters, comments on the general appearance, i.e. color and texture of the material before permeameter testing shall be recorded. The backfill materials and bentonite slurry shall be photographed.

2.3.7 Permeameter Testing. Permeameter testing will be conducted in accordance with the Army Corps of Engineers Manual EM 1110-2-1906 using back pressure saturation and downflow conditions. Flexible wall permeameters shall be loaded with each of the backfill mixtures and leached with RMA tap water until one porewater volume has passed through the backfill mixtures. A total of three permeameter tests shall be run on each backfill mixture. One of the three tests for each backfill mixture will serve as a control test. Control cells will be leached with only RMA tap water throughout the duration of the test, and will consist of the selected mix with the percent bentonite which produced a permeability near 1 x 10EE-7 cm/sec during optimization testing. The remaining two permeameters for each backfill mixture shall be leached with the contaminated ground-water, after one pore volume of RMA tap water has passed. At least two pore volumes of contaminated ground-water will be leached through the backfill mixtures. One of these permeameters will contain the same mix and percent bentonite as the control cell. The other permeameter will contain the same mix as the control cell with a higher bentonite content that produced a permeability close to 1 x 10EE-8 cm/sec during optimization testing. The samples will be compressed into the cell manually in order to reduce the amount of entrapped air.

2.3.7.1 Elevated hydraulic gradients shall be used in order to complete permeameter testing within a reasonable period of time (minimum two months). A pressurized nitrogen source will be used to achieve the required hydraulic gradients. The hydraulic gradient to be applied is 28. The confining pressure to be applied is 5 psi.

2.3.7.2 The permeameter influent will be tested for TOC, specific conductivity, bromide, pH, alkalinity, sodium, calcium, chloride, VOA (Volatile Organics), and BNA (Base Neutral Acid Extractible Organics) immediately prior to permeameter testing. Effluent from the permeameters will be collected and tested for the same chemical constituents after each porewater volume has passed through the sample. This data will be used to estimate the amount of contaminant adsorption/desorption taking place.

2.3.7.3 As the permeameters are opened after completion of the tests, a visual examination of the samples will be performed. The purpose of the visual examination is to determine whether months of testing has altered the general appearance of the sample. Observations similar to those made in

the pre-test examination (color, texture) will be recorded and the samples will be photographed.

2.3.8 Selection of Backfill Mixture. Results of the compatibility study will be used to select the backfill mixture (constituents and proportions) to be used during construction. Selection will be based on:

Permeability (lowest)
Backfill soil alteration (lowest)
Difference in permeability between tap water and contaminated ground-water (lowest)
Field constructibility and quality control (greatest)
Cost (lowest)

The MRD Lab will issue a report on the compatibility study, including all data sheets and calculations. The Final Design Analysis will reference this report and contain a discussion of the results, including the mixture selection.

2.4 Field Vs. Laboratory Permeability. For groundwater modelling purposes, a permeability of 1 x 10EE-7 cm/sec was assumed for the in situ slurry wall backfill. Using that permeability, a wall thickness of 3 feet, and a head differential of 3 feet across the wall, the calculated time for water to flow through the wall is 20.5 years (see calculation sheets, Appendix A). However, Darcy's Law takes into account advection of water only, while diffusion and dispersion of contaminants generally causes them migrate faster than water. At very low permeabilities, some studies have shown diffusion and dispersion predominate over advection as a means of contaminant transport. Research has been done to quantify diffusion and dispersion for individual contaminants, but the effects of multiple contaminants is largely unknown. During the life of the wall, water levels inside and outside the cell will be monitored to assure a negative head into the wall. An extraction trench near the north boundary will be used as necessary to maintain a negative head. The designers have decided not to specify a laboratory permeability an order of magnitude lower than the anticipated field permeability. With proper specification and field quality control (i.e., mix design, frequency of QA/QC testing, full mixing) the field permeability should not be severely compromised. If unexpected water flows into the cell, the extraction system will be utilized to remove it.

2.5 Control of Negative Head within Isolation Cell. Removal of ground water trapped within the isolation cell will be required in order to maintain a lower ground-water level within the cell than that outside the cell. This lower level within the cell will assure that no contaminated ground water will migrate out of the isolation cell. Additionally, ground-water recharge into the cell through the cutoff walls and floor of the cell must be considered. The ground-water level drop across the cell is 13 feet, from elevation 5250 at the south to elevation 5237 at the north. Once the cutoff walls are completed, ground water that is trapped within the cell will begin to seek equilibrium. If an equalized horizontal ground-water level were allowed to occur, this level would be at elevation 5244. The equalization process will automatically effect a negative head (a ground-water level within the cell below that outside the cell) from the south cutoff wall northward for a distance of about 250 feet. Since the soil within the cell (and without) has a low hydraulic conductivity,

ground-water flow toward the north cutoff wall will be very slow. Estimated time to reach equilibrium at elevation 5244 without ground-water withdrawal is 16.3 years (the finite difference ground-water model predicts 16 years). The graphical flow net (see discussion section 2.7, Elevation of Ground-Water Flow Diversion) indicates a slight rise in the ground-water level at the south cutoff wall, from elevation 5250 to about 5255, and a slight drop at the north cutoff wall from elevation 5237 to about 5236. Again, as in the equalization process within the cell, the rise and drop of ground-water levels will occur over many years. Because of this, calculations made for the control of the negative head within the isolation cell are based on an initial ground-water elevation of 5250 at the south cutoff wall and elevation 5237 at the north cutoff wall. Initial design ground-water elevations for the negative head are 5243 near the center of the cell and 5234 at the north cutoff wall. Final designed ground-water level is 5234 across the entire cell. Ground-water extraction is normally accomplished by wells. In this case, however, production wells are impractical. Low hydraulic conductivity, impermeable boundary effects, and well interference conditions are factors that make well extraction impractical. Analyses were made for ground-water removal by wells. The results indicate that maximum production from each well would be considerably less than 1.0 gallons per minute (gpm), about 0.08 gpm. Ground-water removal can be accomplished by a single, horizontal drain located 100 feet south of the north cutoff wall. This location of the drain is dictated by the necessity of lowering the ground-water level in the northern one-half of the isolation cell (the southern one-half will automatically adjust to a negative head). The drain is located slightly closer to the north cutoff wall to provide drawdown to elevation 5234 (about 3 feet) whereas the drawdown near the center of the cell must be at elevation 5243 (about 1 foot). Soil conditions at this location favor the emplacement of the drain at elevation 5227. Ground-water flow to the drain was calculated by quantitative methods outlined by Freeze and Cherry (1979). This method involves prediction of ground-water inflow to a vertical excavated face. The model is partially bounded by impermeable boundaries. The equations for this model are time dependent. The drain does not exactly conform to the model, i.e. vertical open face vs enclosed buried drain and impermeable boundaries at the ends of the drain. Given these conditions, estimated maximum ground-water production during the first 230 days of operation is about 19 gpm. This would result in an average drawdown of about 3.5 feet within the isolation cell. Only a minimal volume of ground-water withdrawal is required to maintain a negative head within the cell. The volume of trapped ground water within the cell above elevation 5234 (the designed ground-water level at the north cutoff wall) is 1,111,600 cubic feet. A withdrawal rate of 5 gpm for 230 days and 2.2 gpm for 396 days will lower the ground-water level to the designed elevation of 5234 at the north wall only in about 1.7 years. Since it will require about 11 years to reach elevation 5236.5 outside the cell, lowering the ground-water level in 1.7 years results in a safety factor of 6.4. Ground-water flow into the isolation cell through the cutoff walls and the floor of the cell will be negligible. The rate of flow is calculated to be about 40 cubic feet per day, about 0.2 gpm. The volume of ground water occurring between elevations 5234 and 5235 is 82,225 cubic feet. The time required to raise the ground-water level from elevation 5234 to elevation 5235 due to recharge through the cutoff walls and floor will be about 5 1/2 years.

2.6 Drain Construction. A 6-inch diameter slotted pipe drain shall be installed in a 3-foot wide trench excavated from ground surface to elevation 5228 at the east end of the drain and to elevation 5226 at the west end of the drain. The pipe drain will lead to a lift station located on the west end of the trench. Centralizers will be placed on the drain pipe to assure centering of the pipe within the trench. Fine aggregate for concrete will be used for filter sand. One foot of filter sand shall be placed in the bottom of the trench for bedding for the drain pipe. The filter sand shall be placed around and above the drain pipe to the elevation of the water table, 5239, in 3-foot lifts. Gradation of the filter sand is in accordance with EM 1110-2-1901, Seepage Analysis and Control for Drains. Random backfill shall be placed from the water table to the ground surface. A biodegradable slurry shall be used for the full depth of excavated trench to prevent sloughing of the sidewalls. The biodegradable slurry shall be clean (desanded or new) prior to the placement of the perforated drain pipe. Slurry and biodegraded slurry removed from the trench shall be considered contaminated and shall not be allowed to leave the isolation cell area and will be spread out over the surface. Design of the filter sand is included in Appendix A.

2.7 Evaluation of Ground-water Flow Diversion. Graphical representations of flow through porous media are called flow nets. Flow nets are an invaluable aid in the solution of various ground-water flow problems. Flow nets are a collection or set of flow lines intersecting a set of equipotential lines. An unlimited number of flow lines and equipotential lines may be drawn, but only a few may be selected to accurately illustrate the general flow condition for the immediate problem. The construction of flow nets involves many intuitive deductions and may be considered an art rather than a science. However, if fixed conditions are the rule at all points of a boundary of a saturated soil mass, a flow net is uniquely determined. That is to say, one and only one solution exists. If, however, there is a change in boundary conditions, a new unique solution will then exist, but it may take a long interval of time to achieve steady state conditions. One flow new and one ground-water flow diagram were constructed to determine the possibility of diversion of contaminated ground water into non-contaminated or less contaminated areas. The flow net and ground-water flow diagram are included in Appendix A. The only information a priori for the flow net were ground-water levels measured in 1989. A pre-construction flow diagram was constructed for comparison with a post-construction flow net. Although a uniform saturated thickness was assumed for the construction of the flow net, the error introduced will only have minimal effect on the study. The resultant upgradient and downgradient potentials from the post-construction flow net were estimated based on the configuration of a priori equipotential contours. The study indicates that there will be a rise in ground-water level at the south wall of the slurry trench (upgradient) of about five to six feet (elev. 5255 to 5256). Conversely there will be a drop in ground-water level at the north wall of the slurry trench (downgradient) of about one foot (elev. 5236). The finite difference ground-water flow model predicts a rise only to elevation 5252.5 south of the isolation cell, and a drop to elevation 5237 north of the cell. Flow lines of the net indicate that ground-water flow will be diverted about equally east and west of the containment cell. The ground-water flow will parallel the sides of the containment cell and then will converge north of the containment cell, again nearly following the flow path that the ground-water regime had prior

to the construction of the containment cell. It is concluded that there will be no significant diversion of the ground-water flow regime.

2.7.1 **Ground-water Flow Model.** A finite difference ground water flow model was used to simulate ground water flow in the alluvial aquifer of the lime settling basin area at Rocky Mountain Arsenal. Software used to develop the model is part of the Well Field Simulation Package developed by Hall Groundwater Consultants. The model is based on a finite difference computer model developed by Prickett and Lonnquist (1971) which has been modified by Hall Groundwater to run on IBM PC compatible computers.

2.7.1.1 The data base used to develop the model was drawn from a bedrock elevation map and a groundwater elevation map prepared by Woodward and Clyde Consultants. Data required for the finite difference grid nodes were extrapolated from these two maps. Permeability of 2.12 gallons/day/foot^2 (1×10^{-4} cm/sec) was used for the model. This value was confirmed by a series of slug tests recently conducted by Woodward and Clyde Consultants. The storativity used for the model was 0.2. Modeling was conducted in three phases. Two finite difference grids were used. The first two phases of modeling were based on a symmetrical, 29x29 grid. Grid spacing varied between 200 feet, at the outer margins, to 50 feet within the area of the lime settling basin. The third phase of modeling used a 29x26 grid with a constant node spacing of 25 feet. Model configurations are included in appendix A.

2.7.1.2 Initial modeling used only data input from the groundwater elevation and bedrock elevation maps in order to calibrate the model. Boundary conditions were varied during this phase of modeling to most closely approach the current groundwater conditions at the Lime Settling Basin. The closest approximation to actual conditions at the Lime Settling Basin Site was achieved by setting up all of the boundaries as constant head boundaries. In the Hall Groundwater Model a constant head boundary is modeled by using an extremely high storativity value in the nodes which define the boundary. A value of 2×10^{12} was used for this modeling.

2.7.1.3 The model was calibrated by simulating existing head conditions in the unconfined aquifer. Results of the calibrations are included in appendix A. After the model was calibrated, the slurry wall was input into the model by reducing the permeability at the nodes which define the position of the wall by three orders of magnitude relative to background. A value of .00212 gallons/day/foot^2 (1×10^{-7} cm/sec) was used for the slurry wall permeability. Boundary conditions were the same as in the first phase of model runs. These model runs were used to determine the effects of the slurry wall on the local groundwater flow system and to compare the computer generated flow system with a flow net which was generated, based on hand calculations, prior to the start of computer modeling. The match between the computer generated flow system and the flow net matched over most of the model. There were slight differences between the two flow systems near the northern boundary of the slurry wall because of a minor difference in extrapolated groundwater head contours used in developing the two models. The results of the modeling of the flow overall flow regime within and surrounding the isolation cell are included in appendix A. The computer simulation indicates a slight rise in ground-water level upgradient of the isolation cell (about 2.5) feet, and a slight drop downgradient

(about 2 feet). The ground-water is shown as equalizing within the isolation cell at about elevation 5245. Total time to attain stabilized ground-water flow after construction of the isolation cell is about 11 1/4 years.

2.7.1.4 The third phase of modeling was concerned only with flow within the confines of the slurry wall. Model boundaries were determined by the position of the slurry wall over much of the model, where the boundary was set as a no flow boundary. In the northern part of the model boundaries were set up as constant head boundaries. While a constant head boundary in this location is not realistic, the relative impermeability of the slurry wall makes the effects of a constant head boundary negligible, considering it was only with the interior of the slurry wall area that this phase of modeling was concerned. Results of the modeling indicate that the groundwater will stabilize within the isolation cell at about elevation 5243 in about 19 1/2 years. This model simulation does not consider any ground-water removal from the isolation cell. Results of the modeling are included in appendix A.

2.7.1.5 A row of pumping wells was input within the slurry wall area 100 feet south of the north slurry wall to try to simulate the effects of a drain. Ten wells were simulated and at all pumping rates ground-water withdrawal was so rapid the wells were considered to be pumped dry by the model. The model run of a pumping rate of 0.10 gpm resulted in a drawdown to about elevation 5235.5 at the north wall of the isolation cell. The pumping dry of the well is a result of a combination of boundary effects and the low permeability of the material that makes up the aquifer. The results of the computer modeling of ground-water withdrawal are included in appendix A.

2.8 Evaluation of Bedrock Aquifer Contamination. A piezometer cluster is located 50 feet east of the east wall of the isolation cell at coordinates N 2,185,002; E 181,126. This cluster has separate piezometers installed in the alluvium and the Denver "A" sandstone unit which is 34.5 feet below the top of bedrock. Ground-water elevation in alluvium was measured at elevation 5248 and ground-water elevation in the Denver "A" sandstone unit was measured at elevation 5254. These measurements were made in April 1990. The measurements indicate there is a downward hydraulic gradient into the Denver formation of 0.032 ft/ft. The designed elevation of ground-water within the isolation cell to maintain negative head is 5234. This will result in an upward gradient from the Denver "A" sandstone unit into the isolation cell of 0.26 ft/ft. Since the gradient is upward into the cell, there will be no contamination of the Denver Formation from the isolation cell. Ground-water flow from the Denver Formation into the isolation cell is calculated to be about 25 cubic feet per day. Calculations concerning bedrock contaminations are included in appendix A.

2.9 Alignment of Slurry Wall. It was observed during site visits and reviews of current aerial photography and 1940's topographic maps, that the extent of sludges deposited outside the Lime Settling Basins could be possibly up to 10 feet in depth. Information from the investigative borings confirm that sludges deposited north of the Lime Settling Basins are approximately 7 to 9.5 feet in depth, approximately 1 to 2 feet in depth on the area west of the basins, and 1 to 2 feet in depth on the south side area of the basins. The option to place the slurry wall around the existing Lime Settling Basins only, did not provide enough storage capacity to contain all the excavated contaminated sludges

outside the Lime Settling Basins. It was felt that the deposited sludges outside the existing Lime Settling Basins should also be contained within the slurry wall isolation cell, as they could be considered a contaminant source. The alignment of the Slurry wall around the Lime Basins was extended to the north in order to contain more contaminated in-situ sludge material, and provide for more storage capacity of excavated contaminated soils. The area contained by the slurry wall isolation cell is directly adjacent to Basin A, and therefore the slurry wall will be constructed through contaminated soils. The slurry wall will not completely surround the contaminated area, but it will contain the contaminated source area of the Lime Settling Basins.

2.10 Slurry Trench Width and Depth. The width of the slurry trench will be 3 feet. The depth of the slurry trench was estimated to have a maximum depth of 35 feet from the ground surface and an average depth of 28 feet. The trench will be keyed into the Denver Formation claystone 2 feet. Establishment and maintenance of a negative head within the isolation cell will only require that the bottom of the trench be excavated through the overburden material. Emplacement of the slurry wall through the overburden will eliminate excessive recharge into the isolation cell. Only slight leakage, if any will occur through the claystone and into the cell when the slurry wall is keyed two feet below the top of bedrock. Whenever uncemented, loose fine-grained sandstone is encountered at the top of bedrock, it will be excavated to the depth of cemented, hard fine-grained sandstone or claystone whichever is encountered first. The cemented sandstone has a low permeability, 1.0×10^{-5} cm/sec or less, and will not appreciably affect the recharge into the isolation cell. Average depth of excavation into the Denver Formation is anticipated to be just slightly greater than two feet.

2.11 Construction.

2.11.1 Work Zones. The exclusion, contaminant reduction, support, and staging zones are shown in the drawings. The support zone is located west of the Lime Basins, north of the RMA Fire Station. The staging and contaminant reduction areas are located just east of the support zone. Arsenal personnel do not want heavy dump trucks loaded with off-site borrow soil to access the site via December 7 Avenue because the trucks might damage the pavement. Therefore a gravel access road will be built accessing the site from the east. To keep that road clean, empty trucks will exit the site via the southwest.

2.11.2 Grading. Minor grading will be necessary to provide a construction platform for the slurry wall installation. The work platform will be 40 feet wide and have a maximum slope of 1% along the slurry wall centerline. Since the existing surface soils are contaminated, the work platform will be covered with 12" of clean borrow material in order to provide a clean area on which to work.

2.11.3 Excavation. Excavation of the trench will be made with a large track mounted extended-reach backhoe or by a crane-mounted slurry-trench clamshell. The trench is kept from collapsing by the bentonite slurry. Water for slurry mixing operations is available from the water truck filling facility at the RMA Fire Station. Excavated materials will be placed in the isolation cell, if it is determined during compatibility testing that the material is

unsuitable for backfill. The Contractor will have the option of performing the overexcavation of contaminated materials on the south, north, and west of the Lime Basins either before or after construction of the slurry trench.

2.11.4 Sequential Construction Evaluation. An evaluation of sequential construction of the slurry trench has been made to determine if a significant lowering of the ground-water table will occur during the construction of the isolation cell. Once the south cutoff wall has been constructed, ground-water lowering will occur on the north side (eventually in the trapped portion of ground water within the cell). The greatest lowering (or escape out of the cell) of ground water as a result of sequential will occur if excavation is started at the north end of the east cutoff wall. The excavation must then proceed southward for excavation of the east wall thence continuing around the isolation cell until completion of the cell is made by connecting to the north end of the east wall. It is calculated that 5,310 cubic feet of ground water will escape the isolation cell because of this sequential construction. This amount is insignificant when compared to the amount that must be removed (about 1,111,600 cubic feet) for maintenance of a negative head. Since sequential construction will place a restriction on the contractor's operations, which is not cost justified, sequential construction of the slurry wall will not be specified. Calculations concerning sequential construction are included in appendix A.

2.11.5 Slurry Preparation. The Contractor will choose the method of mixing slurry. It is anticipated slurry will be mixed by a bulldozer on a concrete pad or by a high velocity mixer. The method, design, and rationale for the slurry mixing operation will be a Category I submittal.

2.11.6 Stability. The stability of a 28-feet deep (average) slurry trench is not anticipated to be a major concern, since trenches over 100 feet deep have been successfully completed by others.

2.11.7 Backfilling. Backfill material will be blended and trucked to the trench where it will be moved into the trench with a bulldozer. Blending operations are typically done with a pug mill operation or by mixing with a bulldozer on a concrete mixing pad. The Contractor will select the method of blending the backfill material. Blending operations will be done in the Contractor's staging area. The method, design, and rationale for the chosen mixing method will be a Category I submittal.

2.11.7.1 Backfill Rate. The Corps guide spec states the toe of the slope of the trench excavation shall not precede the toe of the backfill slope by less than 50 feet or more than 105 feet (although those values may be changed). Xanthakos states there is no real reason for specifying somewhat arbitrary distances, and says that the minimum distance would be the distance the Contractor would need to properly clean the bottom of the trench, which he states is approximately 30 feet. EPA-540/2-84-001 recommends the distance be minimized for stability reasons, but states it may be up to 200 feet. D'Appolonia recommends having slurry in the trench for at least 24 hours prior to placing backfill to allow for proper filter cake formation. None of the references checked listed any method or reason for specifying a maximum distance between the toe of the excavation slope and the toe of the backfill slope.

Therefore the specification states that the distance will be kept to the minimum value which will allow both cleaning of the trench bottom and a minimum 24 hours between slurry placement and soil-bentonite backfill placement. Because a formal stability study was not undertaken, it will also be specified that the distance shall not be greater than 105 feet without the approval of the Contracting Officer.

2.11.8 Bends in Alignment. The slurry trench will be overexcavated at corners to assure the full depth of the trench for at least 2 feet outside the isolation cell.

2.11.9 Compacted Clay Trench Cover. To prevent the soil-bentonite backfill mixture from desicating, the top one foot (cut out of the work platform) will be covered with compacted clay obtained from the previously mentioned clay borrow area used during Basin F remediation. The cover will be 8 feet wide and will be placed between 2 and 4 days after backfilling. At this time it may only be compacted with a backhoe bucket or small hand-operated smooth drum roller because the soil-bentonite backfill may still be somewhat soft. Two weeks after backfilling, the cover will be recompacted with standard compaction equipment and any areas of settlement will be filled in with more clay material and compacted. At this time the Contractor will excavate two areas of the trench to be used as heavy equipment crossings during subsequent construction. The crossings consist of 2 18-inch and one 12-inch layer of compacted clay separated by geotextiles as shown on the plans. The crossing design is similar to that used on the Kane and Lombard Superfund Site. During construction of the vegetative cover, the compacted clay wall cover and the work platform will be covered by random fill, topsoiled, and vegetated.

2.11.10 Quality Assurance/Quality Control. The Quality Control program for this project is similar to that of the Helen Kramer Landfill site. QA/QC testing of materials is given in Tables 1 and 2 of specification section 02214, Soil-Bentonite Slurry Trench Cutoff. These tables are given in Appendix A. In addition, soundings to determine the top of bedrock, trench bottom, and backfill slope will be made at horizontal intervals of 20 feet. Undisturbed samples of the completed trench for permeability testing will be taken every 400 lineal feet.

2.11.11 Abandonment of Existing Wells and Piezometers. Wells and piezometers 36055A, 36055B, 36058, 36059, 36076, 36167, and 36194 in the Lime Settling Basins area and 01503 and 01504 in the M-1 Basins area will be abandoned. The abandonment is required because the wells and piezometers are located in the construction area. The abandonments will be accomplished prior to other construction activities. Abandonment will be in accordance with RMA policy. Concrete pads will be broken and removed; surface protective, steel casings will be pulled and removed; and the remaining PVC casings and screens will be overdrilled with a hollow stem auger. A cement-bentonite grout mixture of 94 pounds of Type II Portland cement, 3 pounds of powdered bentonite and a maximum 8 gallons of water. The grout will be placed in the overdrilled hole by tremie pipe beginning at the bottom and continuing to the ground surface while the auger sections are removed. A complete record of original well installation data and well abandonment procedures and data will be made for each abandoned well and piezometer.

2.12 LONG TERM MONITORING. Long term monitoring for ground-water quality and piezometric levels will be required to assure the isolation cell is performing as designed. This will be made possible by installation of monitoring wells and piezometers. Monitoring wells will be placed upgradient, and downgradient of the isolation cell and crossgradient on each side of the isolation cell. These wells will be placed near the center of the alignment of the east, south, west, and north walls of the isolation cell. One monitor well will also be placed inside the isolation cell near the center of the north wall. Piezometers will also be placed near the centers of the alignments of the walls and will be located very close to the walls. The piezometers will be inside and outside (mirror imaged) the isolation cell to closely monitor for the maintenance of the negative head within the cell. The locations of monitor wells and piezometers are shown in the Contract drawings.

2.12.1 Construction and Installation of Monitor Wells and Piezometers. Construction and installation of monitoring wells and piezometers will follow procedures outlined in MRD Policy Letter #90-001. The construction will consist of installation of 4-inch ID (for monitor wells) and 2-inch ID (for piezometers) PVC, threaded casings and continuous wire wound type screens; end caps; no grease of oils (other than vegetable oils) will be allowed. Designed sand filter packs, bentonite seals and cement-bentonite grout will be required. Well and piezometer development will be required and turbidity of the water will be measured after development has been completed. Design of the filter sand is included in appendix A. Diagrams of the monitor wells and piezometers are shown in the Contract drawings.

3. VEGETATIVE COVER (LIME SETTLING BASINS).

3.1 **Design**. The cover to be constructed is intended to be a vegetative cover over the Lime Settling Basins. This cover will minimize infiltration and promote drainage away from the Lime Settling Basins. The substantive standards contained in 40 CFR 264.310, specifically those requirements contained in subsections a(2)-(4), and b(1) and (4), describe the necessary standards relevant to this cover. The cover will consist of 12" of compacted fill material and topped with 6" of topsoil. The cover will have a minimum slope of 2 percent to promote drainage. The cover will be seeded with an appropriate seed mixture to minimize erosion to less than 2 tons/acre/year. The Hydrologic Evaluation of Landfill Performance (HELP) Model has been used to determine rainfall infiltration rates through the vegetative cover. Infiltration rates are currently estimated to be less than 0.012 inches/year. A summary of the HELP Model Analysis is located in Appendix A.

3.2 Pond Dewatering and Filling. The Lime Settling Basins will have approximately 2 acre-feet of water removed prior to fill material placement. Pending the results of the water quality testing, the water will be drained into the drainage located to the northeast of the Lime Settling Basins, which eventually flows into Basin A. Impacts of the additional water to Basin A will be evaluated. Other options include the construction of a lined evaporative pond which could be used to store the water until evaporated. The evaporative pond would be lined with a geomembrane to prevent infiltration into the ground. Once

drained, the Lime Settling Basins will be filled with clean fill material up to the existing ground water elevation of approximately 5248.

3.3 Contaminated Excavations. Contaminated soils outside the slurry wall containment cell, located to the south, west and north, will be excavated and placed inside the containment cell. Newly placed contaminated soils will be placed above ground-water level. Dust control will be critical during all excavations.

4. SHEET PILE CUTOFF WALL (M-1 SETTLING BASINS)

4.1 Criteria. The Decision Document requires the containment system consist of a 360 degree subsurface barrier around the M-1 Settling Basins, vitrification of soil/sludge by introducing an electric current through an array of electrodes, an offgas treatment system for capture of organics, air monitoring during implementation, and ground-water monitoring to evaluate the continued effectiveness of this ISV alternative. Steel sheet piling was determined to be the preferred barrier to be installed. Sheet piling will allow quick, easy installation, and provide temporary containment of the ground-water during the ISV process. The sheet piles will be removed after vitrification.

4.2 Location and Alignment. Information supplied by Geosafe Corporation, the ISV vendor (Application and Evaluation Considerations for In Situ Vitrification Technology: A Treatment Process for Destruction and/or Permanent Immobilization of Hazardous Materials, April 1989), a very steep thermal gradient, approximately 150-200 degrees C per inch, precedes the advancing melt surfaces. Typically, the 100 degrees C isotherm is less than 1 foot away from the molten mass. It was decided to locate the sheet pile 10 feet away from the design limits of vitrification in order to provide adequate room for ISV operations.

4.3 Key Depth. The sheet piles will be driven one foot into the bedrock surface, or until refusal. The boring logs along the sheetpile alignment show bedrock at a depth of 9 to 14.5 feet, generally 9 feet on the south boundary increasing to 14.5 feet on the north boundary.

4.4 Compatibility With Contaminated Groundwater. The sheet piling is a temporary measure to reduce the flow of groundwater into the area prior to and during vitrification primarily to save electricity (and therefore money) by reducing the amount of water that is evaporated during vitrification. The Rocky Mountain Arsenal Project Manager (PMRMA) has indicated the time between sheet pile placement and vitrification will be on the order of a few months. For this reason, compatibility of the steel with the contaminated groundwater is not considered to be a problem and no compatibility testing will be done.

4.5 Pile Sizing. The pressures against the pile and bending moment of the pile are not anticipated to be major concerns, since no excavation will take place inside the cell. The vitrification process does result in a volume decrease and therefore subsidence of the ground surface, but experience at other vitrification projects has shown this to be only a few feet. Since the vitrified mass will be several feet from the sheet piling, the full amount of subsidence will not take place against the sheetpiling but several feet away from it. After

vitrification the subsided area will be filled in with clean soil to avoid leaving a depression in the area. Therefore the major consideration in pile sizing is to survive the driving process. Piles used for the cutoff wall will be PZ22 steel sheetpile.

4.6 Construction.

4.6.1 Sheet Pile Installation.

4.6.1.1 Work Zones. The work zones for construction are shown on the drawings. The Exclusion Zone extends 10 feet outside the sheet pile wall centerline. The Contractor will store his equipment and perform all operations from the inside the area to be surrounded by the sheet pile. The Arsenal does not want workers straying outside the exclusion zone since that area is also contaminated. A note has been placed on the drawings stating that workers are not to go outside of the work zones.

4.6.1.2 Vibrations. There is concern vibrations produced during pile driving may damage adjacent structures. Of major concern to the Arsenal is an underground rigid asbestos water line located just south of December 7 Avenue (about 50 feet north of the northern pile boundary). Research and experience in the field of soil dynamics has shown that peak particle velocity is the parameter most closely related to vibratory damage of structures. As long as peak particle velocity is less than 1 or 2 inches per second damage will not occur. One inch per second is about the lowest vibration most people can perceive. Vibratory hammers produce much less vibration than impact hammers, and this job will be specified as vibratory hammer only. Figure 7 of "Construction Vibrations: State-of-the-Art" (ASCE Journal of the Geotechnical Engineering Division, February 1981) shows that at a distance of 50 feet, the peak particle velocity produced by a vibratory hammer will be approximately 0.3 inches per second. The project plan calls for demolition of above ground structures inside the sheet piling and up to 10 feet outside the sheet piling. According to Figure 7, at a distance of 10 feet a vibratory hammer will produce a peak particle velocity of about 2 inches per second. It is possible structures between 10 and 25 feet away from the driving might receive some damage. However, these structures are not in use now and most probably never will be used again. Any damage that might occur would be minor concrete cracking, as the peak particle velocities are not high enough to cause adjacent structures to collapse. Therefore, it is not anticipated vibrations will be a problem beyond 10 feet. As a precaution, four settlement monuments will be installed in the area prior to driving. Two will be located near the previously mentioned water line about 50 feet north of the north side of the sheetpile, one will be located near the overhead pipe just north of tank T 66, and one will be located just north of the concrete structure 561. The latter two monuments will be approximately 15 feet from the east and south boundaries of the sheetpile respectively. These monuments shall be monitored daily for the first several days of driving and when driving is occurring close to the monuments. If settlement is observed, the Contractor may have to adjust his operations. After the sheet piles are driven and in place, the piles will be cut off to be flush with the existing ground.

4.6.2 Sheet Pile Removal. The sheet piles will not be removed under this contract, but will be removed by others in the future.

4.6.3 Abandonment of Existing Wells and Piezometers. Abandonment of existing wells and piezometers in the construction area will be in accordance with RMA Standard Operating Procedures and/or MRD Policy Letter #90-001.

4.7 **LONG TERM MONITORING**. Long term monitoring of the M-1 Basins will be done by others and is not required in this contract.

5. CIVIL: GRADING, PAVING, AND DRAINAGE. (LIME SETTLING BASINS)

5.1 **DESIGN REFERENCES**. The following references were used in preparing the grading, paving, and drainage design:

5.1.1 Department of the Army and Air Force Technical Manuals.

TM 5-820-1 88-5, Chap 1	Surface Drainage Facilities for Airfields and Heliports (Aug 87)
TM 5-820-4 88-5, Chap 4	Drainage for Areas Other Than Airfields (Oct 83)
TM 5-822-2 88-7, Chap 5	General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas (July 87)
TM 5-822-5 88-7, Chap 3	Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas (Oct 80)

5.1.2 Department of the Army Technical Manuals (TM).

5-820-3	Drainage and Erosion Control, Structures for Airfields and Heliports (Jan 78)

5.1.3 **Engineer Manuals (EM).**

1110-2-2902	Conduits, Culverts and Pipes (Mar 69)

5.1.4 **NEENAH Foundry Company Publication.**

Inlet Grate Capacities for Ponded Water

5.1.5 **Engineering Technical Letter (ETL)**

1110-1-140	Pavement Design for Roads, Streets, and Open Storage Areas (July 88)

5.2 **GRADING.** The following criteria was used to develop site grading.

5.2.1 Crown grade of 2 percent.

5.2.2 Maximum desirable ramp grade of 7 percent. Absolute maximum ramp grade of 10 percent for short distances only.

5.2.3 Minimum grade of 1 percent for overlot grading for cohesionless sandy soils and 2 percent for cohesive soils or turfed areas.

5.2.4 Minimum ditch grade of 0.3 percent.

5.2.5 Maximum foreslopes of 1V on 4H and backslopes of 1V on 3H.

5.3 **FLEXIBLE PAVEMENT.** The temporary construction access road was designed for a drivable surface for construction equipment and for dust control.

5.3.1 Traffic consists of the following vehicles:

1) various construction equipment including dump trucks and earth moving equipment.

5.3.2 **Strength Method.** (Non-Frost Design)

Class = E
Category = IV
Design Index = 4
CBR = 7
Design Thickness = 12 inches

5.3.3 Recommended Pavement Section.

6-inches Crushed Rock Surface Course
6-inches Crushed Aggregate Base Course
6-inches Compacted Subgrade (95% maximum density)

5.4 **DRAINAGE.** Drainage was designed in accordance with AFM 88-5, chapter 1 , TM 5-820-3, and TM 5-820-4. The existing storm drainage system was extended and routed around the lime settling basin. The 30-inch diameter Reinforced Concrete Pipe (RCP) was partially removed, to clear the slurry trench, capped, and abandoned in place. This 30-inch RCP was previously abandoned and capped upstream and carried no storm discharge. The 24-inch RCP was removed to the last down stream manhole and extended from this location. Due to the small drainage area added to this drain line no increase in pipe size was required.

5.4.1 **Storm Drain Pipe.** Storm drains were designed to withstand earth dead loads as well as H-20 or HS-20 highway live loads.

5.4.1.1 **Pipe Materials.** Reinforced Concrete Pipe (RCP) was chosen to match the existing storm drainage system.

5.4.1.2 **Pipe Joints.** Watertight pipe joints were required to prevent infiltration of soils through the joints due to the presence of ground water at or above the pipelines and the use of erodible backfill materials.

5.4.2 Inlet Capacity.

5.4.2.1 **Area Inlets.** The capacity of area inlets in a sump condition was determined using the nomograph in the NEENAH Foundry Company publication entitled "Inlet Grate Capacities for Ponded Water" for a NEENAH type R-6118 catch basin frame and grate.

6. WATER SUPPLY AND WASTEWATER COLLECTION. (LIME SETTLING BASINS)

6.1 DESIGN REFERENCES. The following references were used in preparing the water supply and wastewater disposal design:

6.1.1 Department of the Army Technical Manuals (TM).

TM 5-814-1	Sanitary and Industrial Wastewater Collection-Gravity Sewers and Appurtenances (Mar 85)
TM 5-814-2	Sanitary and Industrial Wastewater Collection-Pumping Stations and Force Mains (Mar 85)

6.1.2 National Standard Plumbing Code (1983).

6.1.3 Recommended Standards for Sewage Works by the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers (1978 Edition).

6.2 GENERAL. The work under this project consists of containing and pumping contaminated water from within the perimeter of the slurry wall at the Lime Settling Basins. It was determined that the ground-water should be artificially depressed within the confines of the slurry wall in order to prevent the migration of contaminated ground-water away from the project boundary.

6.2.1 The Containment and Pumping system consists of a 36-inch diameter lift station, 1 HP sump pump and 660 feet of 2-inch forcemain. The system is designed to contain the estimated flow rate of 5 gpm from the perforated groundwater collection drain and pump it to the CERCLA Water Treatment Plant. The volume to be pumped is considered a finite amount, necessary to provide a negative head/gradient within the settling basins.

6.2.2. Constructibility was the most significant consideration in the design. The collection drain is to be placed approximately 25 deep in heavily contaminated, water saturated, sandy clays which are not stable enough for normal trench excavation. Therefore, the piping will installed by a slurry method. A standard concrete type lift station would be very difficult to construct in the material at the depths required. Therefore, a 36-inch diameter polyethylene

pipe will be used for the pump chamber because it can be attached to the collection piping above ground and easily lowered into the trench through the slurry.

6.2.3. The 36-inch diameter pump chamber is 33 feet deep and is designed to provide 5 feet of storage volume between the invert of the collection drain and the bottom of the pump chamber. The 5 feet of depth amounts to 265 gallons of storage. At a inflow rate of 5 gpm, the storage volume will take approximately 50 minutes to fill allowing the pump adequate time to cool. The design requires a 1 HP sump pump to operate at 22 gpm at 52 feet of head. With the storage volume available the pump will operate for approximately 12 minutes during each pump cycle. The pump is controlled by three float switches suspended in the lift station. The lowest float switch is the pump "off" control, the second float switch located at the elevation of the collection pipe invert is the pump "on" control and the highest float switch located 1 foot above the invert of the collection pipe is the "alarm" switch. These switches will automatically control the pump operation. However, a manual lift station switch will be provided at the CERCLA Water Treatment Plant to shutdown or turn on the lift station controls. In addition, any alarms at the lift station will be monitored at the CERCLA Water Treatment Plant. The manual control and alarm monitoring will be part of the CERCLA Water Treatment Plant project, however, provisions have been made in this design to accommodate this work.

6.2.4. Approximately 1000 feet of 2-inch forcemain is needed to convey the contaminated water from the lift station to the CERCLA Water Treatment Plant. However, only 660 feet of 2-inch forcemain will be provided under this project because not enough survey is available for entire length of the pipe and the exact location for the CERCLA Plant has not been finalized. The remainder of the piping to the CERCLA Plant will be provided as part of the CERCLA Plant project. The route of the forcemain will be easily identified by new overhead power lines, required to power the lift station, running immediately parallel to the forcemain and the end of the forcemain will be identified with a marking post.

6.2.5. The lift station is designed to facilitate all maintenance without entering the pump chamber. Discharge piping is connected directly to the pump and runs directly up to a union at the top of the manhole which can be disconnected to raise pump and piping from the pump chamber during maintenance activities.

6.3 M-1 BASIN DESIGN. Also incorporated within this design package is the relocation of a fire hydrant and capping of various utilities near the M-1 Basins on the south side of December 7th Avenue to facilitate operability of the ISV process (to be designed/constructed in FY 90 thru 93).

7. CHEMISTRY. No chemical analysis is required by the Contractor other than outlined in the Site Safety and Health Plan (SSHP).

8. ELECTRICAL (LIME SETTLING BASINS)

8.1 General. The electrical design is based on the following codes, standards, publications, etc:

8.1.1 National Electrical Code (NEC) NFPA No. 70-1990

8.1.2 Life Safety Code NFPA No. 101-1990

8.1.3 National Electrical Safety Code (NESC) ANSI C2-1990

8.1.4 Architect Engineer Instruction Manual AEIM 14(Rev. July 1990)

8.2 Scope. This design will provide electrical power for the ground water waste pump located at the lime settling basins.

8.2.1 The new basin M-1 cutoff sheet pile walls will be located near existing 13800V 3-phase lines on both the north and west side of the cutoff wall. These lines will be either removed or relocated by the Rocky Mountain Arsenal's electrical distribution contractor.

8.2.2 A new aerial extension of the existing 13800V 1-phase line will be installed from the existing line west of "D" Street and routed to the west edge of the lime settling basins" cap.

8.2.3 A single phase pole mounted transformer would be provided at the end of the new aerial extension. The transformer will have fused cutoff switch and surge arresters. The transformer secondary will be 240/120V and will be routed above the cap in plastic conduit with an equipment ground. The conductor will be sized for load and distance from transformer to load (voltage drop considerations). A combination circuit breaker type motor starter with weather proof enclosure will be locate near the pump.

8.2.4 A ground fault circuit interrupter 120V, 20 ampere receptacle will be located on or near the combination motor starter.

8.3 Specifications. The following guide specifications will be edited for this project: (See Attachments)

Note that section CEGS-16415-OD would be retitled Electrical Work. In addition, section CEGS-16401-OD will be provided.

9. **Health and Safety**. The specifications for the remedial action will present requirements to ensure that the Contractor performs the work in compliance with applicable regulations, especially 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response". The specifications will require the Contractor to maintain a Safety and Health Program and to prepare a Site Safety and Health Plan (SSHP) covering all work to be performed under the construction contract. The paragraphs below describe background information and decision logic involved in determining specific requirements that will be included in the specifications.

9.1 Site description and contamination characterization.

9.1.1 **Site description**. (General) RMA occupies more than 17,000 acres (approximately 27 square miles) in Adams County, directly northeast of

metropolitan Denver, Colorado. The property was purchased by the US government in 1942 for use in World War II to manufacture and assemble chemical warfare materials, such as mustard and lewisite, and incendiary munitions. Starting in the 1950s, RMA produced the nerve agent GB (isopropyl methylphosphonofluoridate) until late 1969. A significant amount of chemical warfare materials destruction took place during the 1950s and 1960. From 1970 to the early 1980's, RMA has primarily been involved with the destruction of chemical warfare materials. In addition to these military activities, major portions of the plant facilities were leased to private industries, including Shell Oil Company, between 1947 and 1982, for the manufacture of various insecticides and herbicides.

9.1.1.1 M-1 Settling Basins Description: The M-1 Settling Basins are located in the South Plants area, just south of December 7th Avenue along the northern edge of the northwest quarter of Section 1. The basins and the berms surrounding them, all of which are now buried and partially built upon, occupy an area of approximately 34,500 square feet.

9.1.1.1.1 The M-1 Settling Basins were constructed to treat waste fluids from the lewisite facility. Two basins were constructed in 1942, and a third basin was constructed in 1943 when the original two filled with solids. All three were unlined, and each measured approximately 90 feet wide, 115 feet long, and 7 feet deep. In addition to the waste fluids from the lewisite disposal facility, the basins may have contained lesser amounts of waste materials from alleged spills within the acetylene generation building, the thionylchloride plant, and the arsenic trichloride plant, which may have been routed through floor drains and the connecting piping to the basins. The basins also received a considerable amount of mercuric chloride catalyst, possibly from a spill.

9.1.1.1.2 The liquids discharged into the basins first passed through a set of reactor towers where calcium carbonate was added, then through a wood trough into the M-1 settling basins where the arsenic precipitated out of solution. The elutrate was decanted through an 18-inch diameter pipe to the Lime Settling basins in Section 36 where final treatment occurred, prior to being routed to Basin A.

9.1.1.1.3 The M-1 Settling basins were backfilled, probably in 1947, and are now covered with soil. Portions of the basins are covered with structures. The facilities that surround the M-1 Settling Basins area were used in the manufacture of bicycloheptadiene until 1974.

9.1.1.2 Lime Settling Basins Description: The Lime Settling Basins, located in Site 36-4, are in the southwestern portion of Section 36 at RMA and consist of three unlined basins, each approximately 1 acre. The boundaries of the Lime Settling Basins include berms that surround the basins as well as associated materials that separated the basins. The total area of investigation is approximately 210,000 square feet and has an average surface elevation of 5,255 feet above mean sea level (MSL).

9.1.1.2.1 The Lime Settling basins were constructed in the early 1940's to remove arsenic from South Plants wastewater by precipitation. Wastewater was treated with lime at the site to precipitate metals and reduce

arsenic concentrations generated by the manufacture, and later the demilitarization, of lewisite. The basins were also constructed to receive wastewater from the industrial activities at the South Plants until the chemical sewer was constructed in the early 1950s. All wastewater originating from the South Plants area was channeled through the Lime Settling Basins prior to entering Basin A. This water flowed through an underground sewer and into a ditch along the south side of the basins. From the ditch, flow into the basins was controlled. Materials possibly contained within the basins include a reported spill of 500 gallons of mercury catalyst and the disposal of approximately 150 drums of mustard in the basins between 1959 and 1960. Reports also note that the mustard may have been neutralized, and that the term "drum" refers to a volume and not that the material was disposed of in drums.

9.1.2 Contamination characterization. Previous field sampling has shown contamination to be present in soil, ground-water and surface water at the Lime and M-1 Settling Basins. Classes of chemicals detected include organochlorine pesticides, organosulfur compounds, volatile organic compounds, metals, and agent degradation products. Additional field work is currently underway to further characterize the contamination at these sites. Soil and water samples are being collected and analyzed for volatiles, semi-volatiles with DBCP, organochlorine pesticides, thiodiglycol, ICP metals, arsenic and mercury. A detailed list of chemical names, concentration ranges and media in which found will be included after the latest analytical results are received.

9.2 Hazard Assessment and Risk Analysis. The remedial action for the Lime and M-1 Settling Basins will involve a number of tasks/operations. The following is a preliminary list of general tasks/operations. A more detailed description will be available later in the design process.

Mobilization and Site preparation
Demolition of structures
Abandonment, installation of monitoring wells
Construction of slurry walls
Installation of drain/trench system
Excavation of sludge from outside wall
Construction of clay "cap" (cover).
Construction of sheet pile cutoff wall
Seeding
Demobilization and site closeout

The following is a list of general hazards that may be encountered. As the tasks are further defined, detailed hazard analyses will be conducted for each task.

Physical Hazards
- Normal outdoor work hazards: slips, trips, falls, etc.
- Normal construction hazards:
  - Moving equipment
  - Use of power tools
  - trenching hazards
  - falling objects
- Noise
- Heat/cold stress (depending on the time of year)

Biological Hazards
- Poisonous and/or thorny vegetation
- Insect bites, stings
- Snakes
- Diseases carried and transmitted by rodents

Chemical Hazards
- volatile halogenated solvents
- volatile aromatic solvents
- mustard agent-related organic compounds
- herbicide-related organosulfur compounds
- GB agent-related organic compounds
- organochlorine pesticides and pesticide-related compounds
- metals

9.3 **Accident Prevention.** The contractor will be required to follow accident prevention procedures outlined in the USACE Safety Requirements Manual (EM 385-1-1). Some of these requirements (i.e. training, hazard analysis, ...) are addressed in other sections of this Design Analysis. The SSHP prepared by the Construction Contractor will serve as the Accident Prevention Plan (APP) and Activity Hazard Analyses (phase plans) described in EM 385-1-1, thus a separate APP will not be required. Accident reporting requirements will also be addressed.

9.4 **Staff organization, qualification, and responsibilities.** The contractor will be required to develop an organizational structure that sets forth lines of authority, responsibility, and communication. Part of this organization will be personnel responsible for oversight and implementation of the health and safety aspects of this program. Since this site remedial action is being undertaken pursuant to CERCLA, the requirements of 29 CFR 1910.120 apply. Therefore, to ensure a "qualified" person is responsible for health and safety, the contractor will be required to utilize the services of an Industrial Hygienist certified in Comprehensive Practice by the American Board of Industrial Hygiene. The CIH will be required to:

- posses a minimum of 3 years experience in developing and implementing health and safety programs at hazardous waste sites or in the chemical industry,
- have demonstrable experience in supervising professional and technician level personnel, and
- have demonstrable experience in developing worker exposure assessment programs and ambient air monitoring programs.

The CIH will have the primary responsibility for implementation, oversight, and enforcement of the health and safety aspects of this remedial action. It will not be necessary for the CIH to be on-site for the entire duration of field work. A fully trained and experienced Site Safety and health Officer (SSHO), responsible to the Contractor and the CIH, may be delegated to implement and continually enforce the safety and health program and site-specific plan elements on-site. The SSHO will be required to posses:

- a minimum of 1 year experience in developing and implementing health and safety programs at hazardous waste sites or in the chemical industry,
- demonstrated experience in construction safety techniques and procedures,
- a working knowledge of Federal and state health and safety regulations, and
- specific training in personal and respiratory protective equipment program implementation and in the proper use of air monitoring instruments, air sampling methods, and procedures.

Each crew actively working in the contaminated areas will be required to include a fully trained and experienced Safety and Health Technician to perform monitoring and ensure compliance with the approved SSHP.
The Contractor will be required to have at least one person certified in first air/CPR by the Red Cross, or equivalent agency, on-site during all site operations.

9.5 Training. All employees working on-site with the potential for exposure to hazardous substances, health hazards, or safety hazards shall meet the minimum training requirements as specified in 29 CFR 1910.120. These employees will have completed the 40 hour hazardous waste training requirements and have three days of field experience in hazardous waste work. All supervisory personnel will have an additional 8 hours of training as specified for management of personnel and activities associated with hazardous waste site activities. Documentation of this training will be required for all personnel; in addition documentation pertinent to annual refresher courses as required in 29 CFR 1910.120 will also be required. All employees will be required to attend site-specific training covering site hazards, procedures, and all contents of the approved SSHP prior to entering the site.

9.6 Personal protective equipment (PPE). Because of the nature of this work, it is likely that engineering controls and work practices will not provide sufficient control of the hazards, therefore, the contractor will be required to provide personal protective equipment to all affected employees. This PPE shall provide dermal and respiratory protection specific to the site hazards. Selection of appropriate PPE will be based on air monitoring results (for respiratory protection) and an evaluation of the potential for dermal exposure during each task (for dermal protection). The Contractor will be required to establish a written personal protective equipment program in compliance with 29 CFR 1910.120(g)(5). Basic levels of protection will be similar to those listed below. Historical information and past field activities in the Lime and M-1 Settling Basins have indicated the possible presence of chemical agents and their breakdown products. Therefore, the level of PPE required during intrusive activities shall be Level B.

9.6.1 **Level D Protection:**

- Hard hat
- Safety glasses with side shields or safety goggles.
- Work clothing as prescribed by weather.
- Steel toe work boots.
- Hearing protection (if needed)

9.6.2 **Modified Level D Protection (all elements of Level D above plus:)**

- disposable outer coveralls (tyvek or equivalent)
- disposable boot covers.
- Surgical inner gloves.
- Chemically protective outer gloves (as per PPE program).

9.6.3 **Level C Protection:**

- Hard hat
- Work clothing as prescribed by weather.
- Disposable outer coveralls (saranex coated tyvek or equivalent)
- Disposable boot covers
- Steel toe work boots.
- Hearing protection (if needed)
- Surgical inner gloves.
- Chemically protective outer gloves (as per PPE program).
- Air purifying respirator (APR) with appropriate cartridges (selected as per respiratory protection program).

9.6.4 **Level B Protection:**

all elements of Level C except air supplied respirators will be substituted for air purifying respirators.

9.7 **Medical Surveillance.** The contractor will be required to institute a medical surveillance program meeting the minimum requirements established by 29 CFR 1910.120. In order to ensure adequate medical surveillance for the hazards at this site, the contractor will be required utilize the services of a licensed physician who is certified in Occupational Medicine by the American Board of Preventative Medicine, or who, by necessary training and experience, is Board-eligible. The Contractor will be required to provide the physician with a copy of the employees' job descriptions, the SSHP, 29 CFR 1910.120, and Section 5.0 of NIOSH publication 85-115.

9.8 Exposure monitoring/air sampling program (personal and environmental). Because of the potential for airborne contamination, the contractor will be required to conduct air monitoring/sampling in order to establish proper levels of respiratory protection. Background conditions will be established prior to the start of work. As a minimum, real-time air monitoring for organic vapors and dust will be necessary within all work areas of an intrusive nature. Monitoring for chemical agents and arsine may also be required. This monitoring will continue throughout the duration of the activity.

9.8.1 In addition to the real-time monitoring, the contractor will be responsible for ensuring compliance with all requirements of 29 CFR 1910.120(h).

9.9 Standard operating safety procedures, engineering controls and work practices. All pertinent procedures will be addressed and implemented as described in the Contractor's SSHP.

9.10 Site control measures. Because contamination exists at this site, the Contractor will be required to establish work zones and site control measures to prevent the spread of contamination.

9.11 Personal hygiene and decontamination. Whenever employees are potentially exposed to contamination, they will be required to undergo decontamination procedures. The contractor will be required to set forth appropriate decon procedures for each level of protective clothing worn on-site. A personnel decon facility with shower facilities will be required. Details about the disposal of trash, contaminated disposable PPE and decon water will be included in the specifications.

9.12 Equipment decontamination facilities and procedures. The Contractor will be required to decontaminate all equipment that has come into contact with contamination. The Contractor will be required to establish an equipment decon pad in the CRZ.

9.13 Emergency equipment and first aid requirements. The Contractor will be required to have the following items immediately available for on-site use:

9.13.1 First aid equipment and supplies approved by the consulting physician.

9.13.2 Emergency eyewashes/showers meeting the standards of ANSI Z-358.1

9.13.3 Emergency respirators (worst-case appropriate).

9.13.4 Spill control materials and equipment.

9.13.5 Fire extinguishers.

9.14 Emergency response plan and contingency procedures (on-site and off-site). The Contractor will be required to prepare an Emergency Response Plan in compliance with 29 CFR 1910.120(l), which addresses the following elements, as a minimum:

9.14.1 Pre-emergency planning and procedures for reporting incidents to appropriate government agencies for potential chemical exposures, personal injuries, firs/explosions, environmental spills and releases.

9.14.2 Personnel roles, lines of authority, communications.

9.14.3 Posted instructions and a list of emergency contacts (physician, nearby medical facility, fire and police departments, ambulance service, federal/state/local environmental agencies, CIH, Contracting Officer).

9.14.4 Emergency recognition and prevention.

9.14.5 Site topography, layout, and prevailing weather conditions.

9.14.6 Criteria and procedures for site evacuation (emergency alerting procedures/employee alarm system, emergency PPE and equipment, safe distances, places of refuge, evacuation routes, site security and control).

9.14.7 Specific procedures for decontamination and medical treatment of injured personnel.

9.14.8 Route maps to nearest pre-notified medical facility.

9.14.9 Criteria for initiating community alert program, contacts, and responsibilities.

9.14.10 Procedures for critique of emergency responses and follow-up. The Contractor will also be required to ensure all emergency response procedures set forth by RMA are followed.

9.15 Heat/cold stress monitoring. Ambient weather conditions will dictate when heat and cold stress monitoring requirements are appropriate. Ambient temperature readings and the type of clothing worn will affect the type and extent of monitoring required. The contractor will be required to provide and implement protocols for heat and/or cold stress monitoring.

9.16 Sanitation. The Contractor will be required to provide, in the Support Zone, potable water and washing facilities consisting of hot and cold running water, towels and soap for men and women as necessary. (See also paragraph 6.11: Personal hygiene and decontamination.) At least 1 toilet, and if there are more than 20 employees, at least 1 toilet seat and 1 urinal per 40 workers will be required. A sanitary break and lunch area will be required in the Support Zone.

9.17 Logs, reports, and recordkeeping. Proper documentation will be an important part of the remedial action. The contractor will be required to keep the following records:

9.17.1 **OSHA Records.** Required OSHA records are listed in Table 6-1.

9.17.2 Daily log and safety inspection reports. The daily log and safety inspection report shall include practices and events that affect safety and health, safety and health discrepancies encountered and safety and health issues brought to the supervisor's attention. Each entry shall include:

9.17.2.1 Date

9.17.2.2 Work area

9.17.2.3 Employees present in work area

9.17.2.4 PPE and work equipment being used in each area.

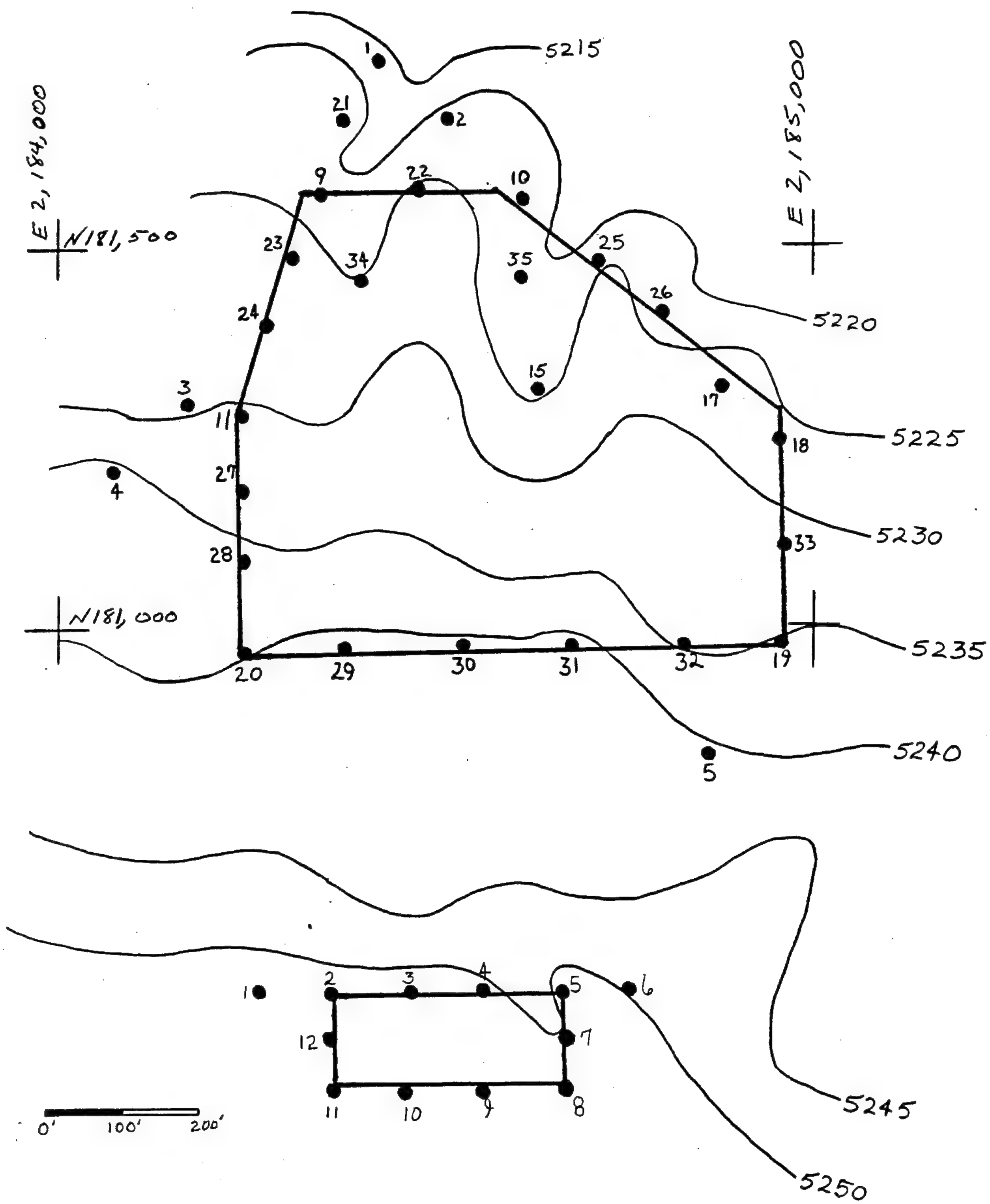
9.17.2.5 Special health and safety issues and notes

9.17.2.6 Signature of preparer.

APPENDIX A

GEOTECHNICAL

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - LSB+M-1		SHEET NO. 1 OF 1	
ITEM Bedrock Contour Map		BY JMC	DATE 10-12-90
		CHKD. BY	DATE



MRO Form 1550, 1 DEC 83

HVORSLEV ANALYSIS

Hvorslev Equation:

$$K = \frac{R^2 \ln (L/R)}{2\ L\ T_o}$$

where:
- K = Hydraulic Conductivity
- R = Radius of Well Casing and Screen
- L = Length of Well Screen
- T_o = Basic Time Lag at Head Ratio = 0.37

LSB-15: Hvorslev Analysis

R = 0.17 ft
L = 5 ft

Falling Head Test: T_o = 9.5 minutes

$$K = \frac{(0.17\ ft)^2 \ln (5\ ft/0.17\ ft)}{2\ (5\ ft)\ (9.5\ min)} = 1.0 \times 10^{-3}\ ft/min$$

Rising Head Test: T_o = 24 minutes

$$K = \frac{0.17\ ft)^2 \ln (5\ ft/0.17\ ft)}{2\ (5\ ft)\ (24\ minutes)} = 4.1 \times 10\text{-}4\ ft/min$$

LSB-34: Hvorslev Analysis

R = 0.17 ft
L = 10 ft

Falling Head Test: T_o = 25 minutes

$$K = \frac{0.17\ ft)^2 \ln (10\ ft/0.17\ ft)}{2(10\ ft)\ (25\ min)} = 2.4 \times 10^{-4}\ ft/min$$

Rising Head Test: T_o = 11.75 minutes

$$K = \frac{(0.17\ ft)^2 \ln (10\ ft/0.17\ ft)}{2\ (10\ ft)\ (11.75\ min)} = 5.0 \times 10^{-4}\ ft/min$$

LSB-35: Hvorslev Analysis

R = 0.17 ft
L = 10 ft

Falling Head Test: T_o = 16.5 minutes

$$K = \frac{(0.17\ ft)^2 \ln (10\ ft/0.17\ ft)}{2(10\ ft)\ (16.5\ min)} = 3.6 \times 10^{-4}\ ft/min$$

Rising Head Test: T_o = 39 minutes

$$K = \frac{(0.17\ ft)^2 \ln (10\ ft/0.17\ ft)}{2(10\ ft)\ (39\ min)} = 1.5 \times 10^{-4}\ ft/min$$

BOUWER AND RICE ANALYSIS

Bouwer and Rice Equation:

$$\ln s_o - \ln s_t = \frac{2\,K\,L\,t}{r_c^2 \ln(r_e/r_w)}$$

where:

- s_o = initial drawdown in well due to instantaneous removal of water from well
- s_t = drawdown in well at time t
- L = length of well screen
- r_c = radius of well casing
- $\ell n(r_e/r_w)$ = empirical "shape factor" determined from tables provided in Bouwer and Rice (1976)
- r_e = equivalent radius over which head loss occurs
- r_w = radius of well (including gravel pack)
- H = static height of water in well
- b = saturated thickness of aquifer

LSB-15: Bouwer and Rice Analysis

L = 5 ft
r_c = 0.17 ft
r_w = 0.42 ft
H = 14 ft
b = 14 ft

<u>Falling Head Test</u>: $s_o = 1.59$ ft

$K = 6.4 \times 10^{-4}$ ft/min

<u>Rising Head Test</u>: $s_o = 1.64$

$K = 3.7 \times 10^{-4}$ ft/min

<u>LSB-34: Bouwer and Rice Analysis</u>

$L =$ 10 ft
$r_c =$ 0.17 ft
$r_w =$ 0.42 ft
$H =$ 13.25 ft
$b =$ 13.25 ft

<u>Falling Head Test</u>: $s_o = 1.76$ ft

$K = 9.6 \times 10^{-5}$ ft/min

<u>Rising Head Test</u>: $s_o = 0.75$ ft

$K = 5.2 \times 10^{-4}$ ft/min

<u>LSB-35: Bouwer and Rice Analysis</u>

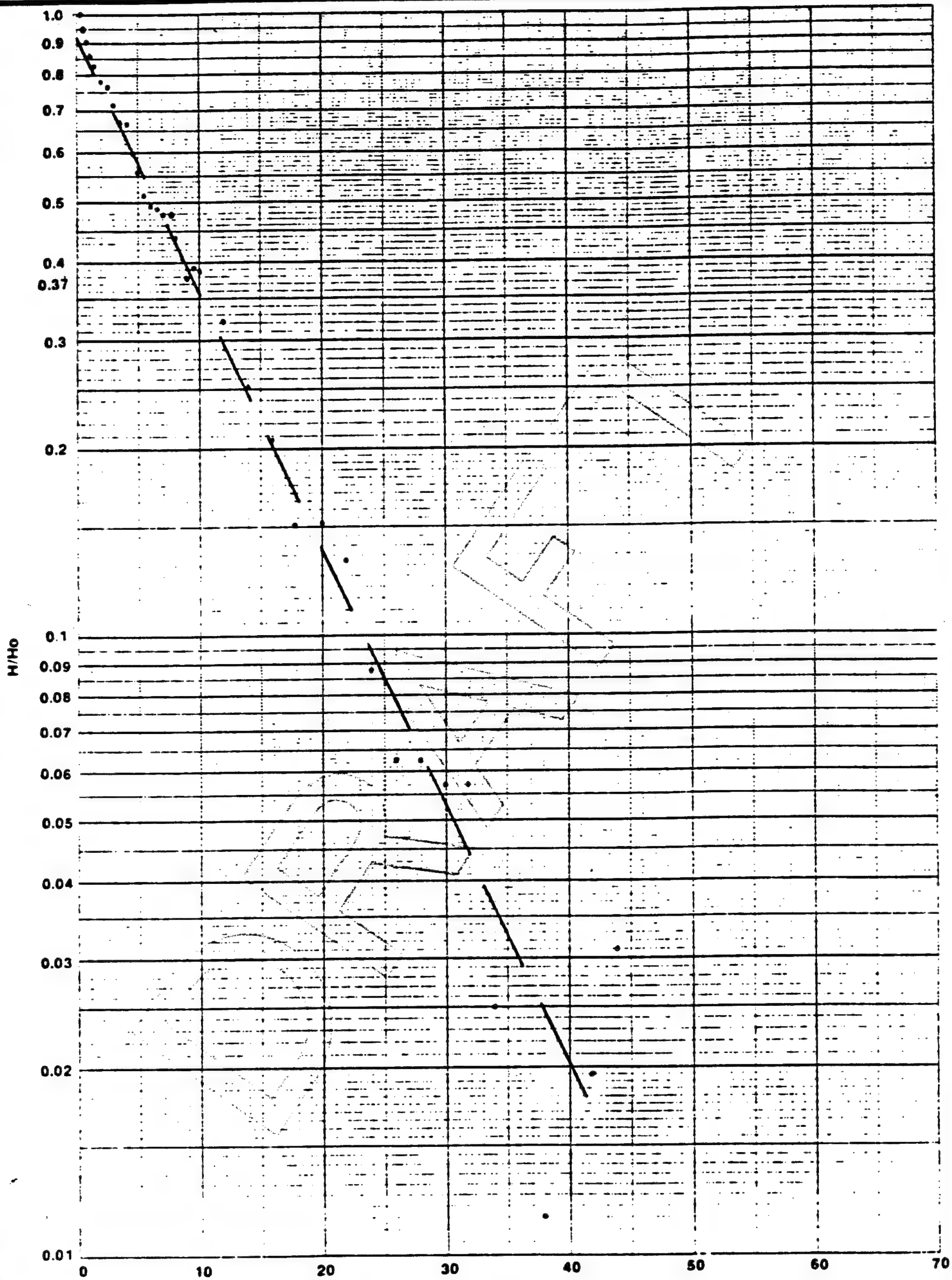
$L =$ 10 ft
$r_c =$ 0.17 ft
$r_w =$ 0.42 ft
$H =$ 19.65 ft
$b =$ 19.65 ft

<u>Falling Head Test</u>: $s_o = 1.70$ ft

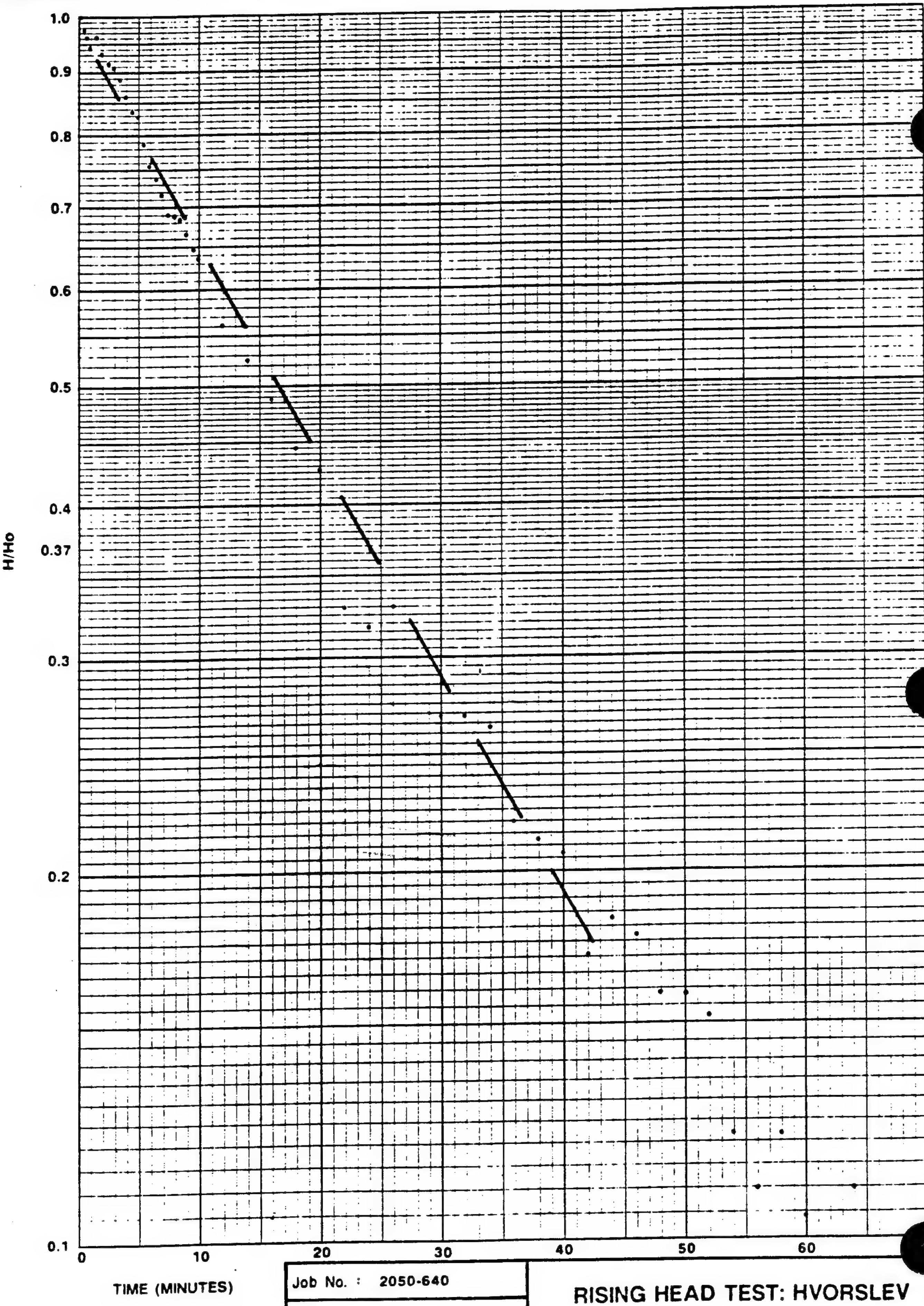
$K = 3.0 \times 10^{-4}$ ft/min

<u>Rising Head Test</u>: $s_o = 1.58$ ft

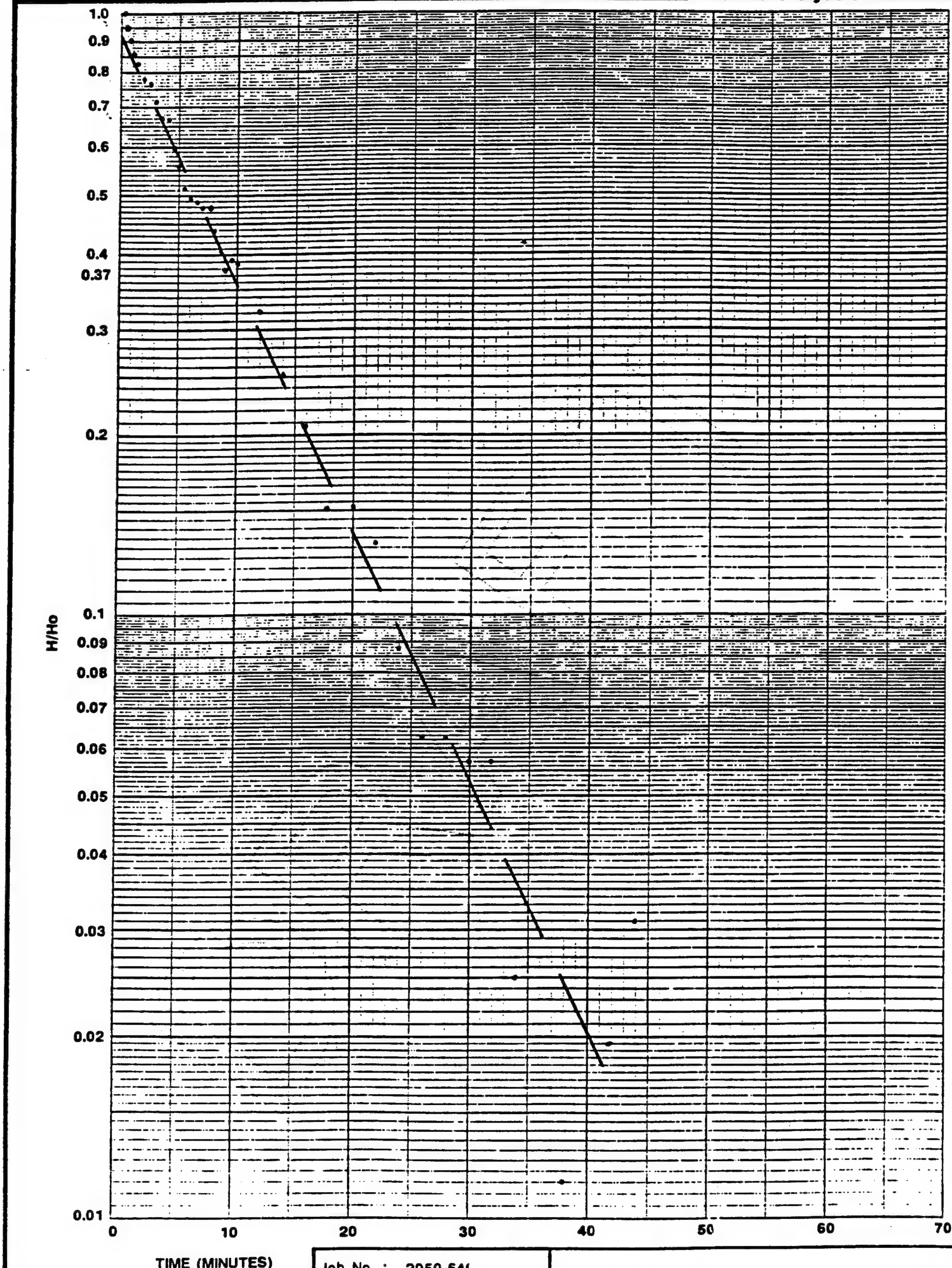
$K = 1.2 \times 10^{-4}$ ft/min



Job No. : 2050-640	FALLING HEAD TEST: HVORSLEV LSB-15
Prepared by: R.L.C.	
Date: 8/23/90	

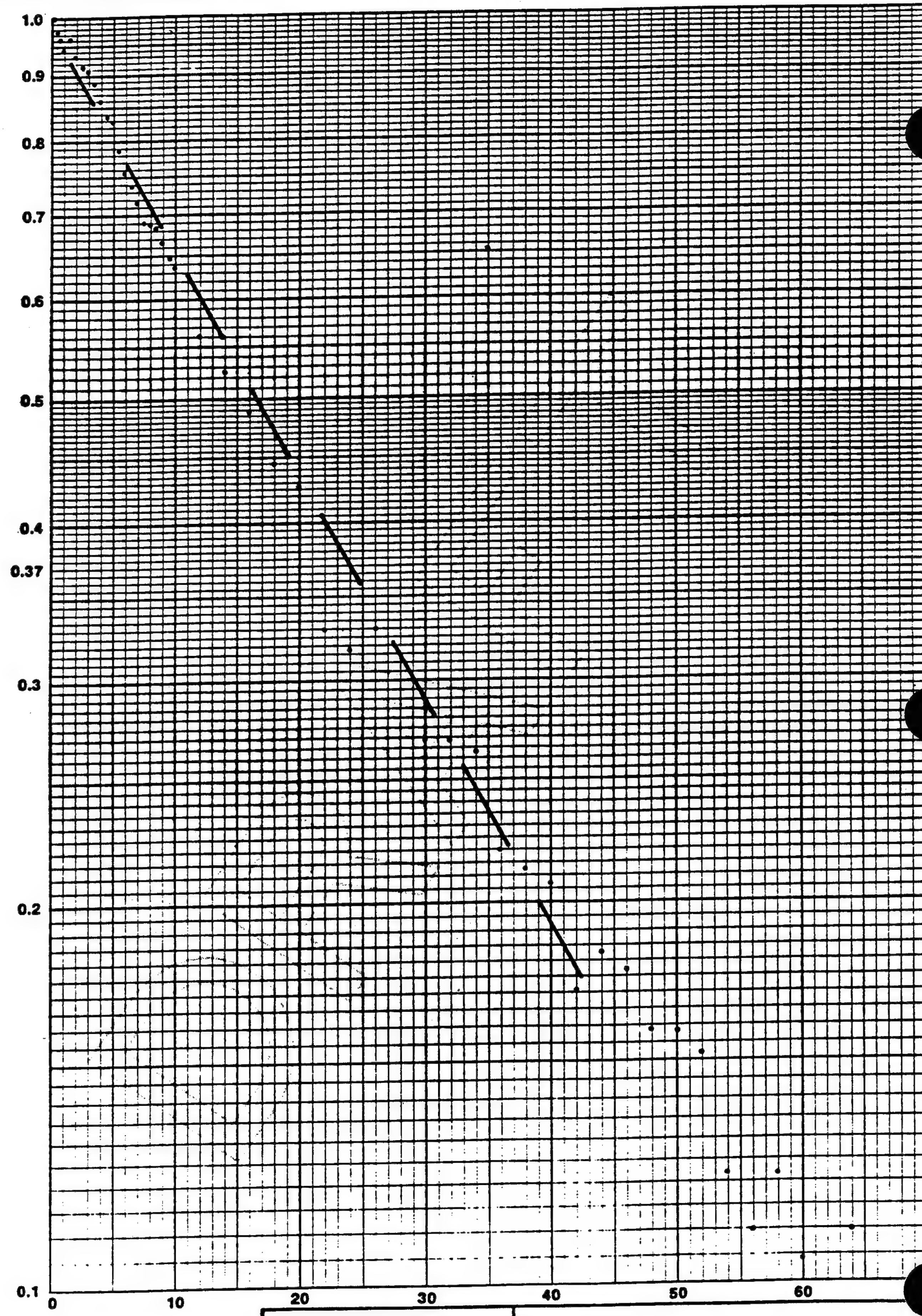


Job No. : 2050-640	RISING HEAD TEST: HVORSLEV
Prepared by : R.L.C.	LSB-15
Date : 8/22/90	



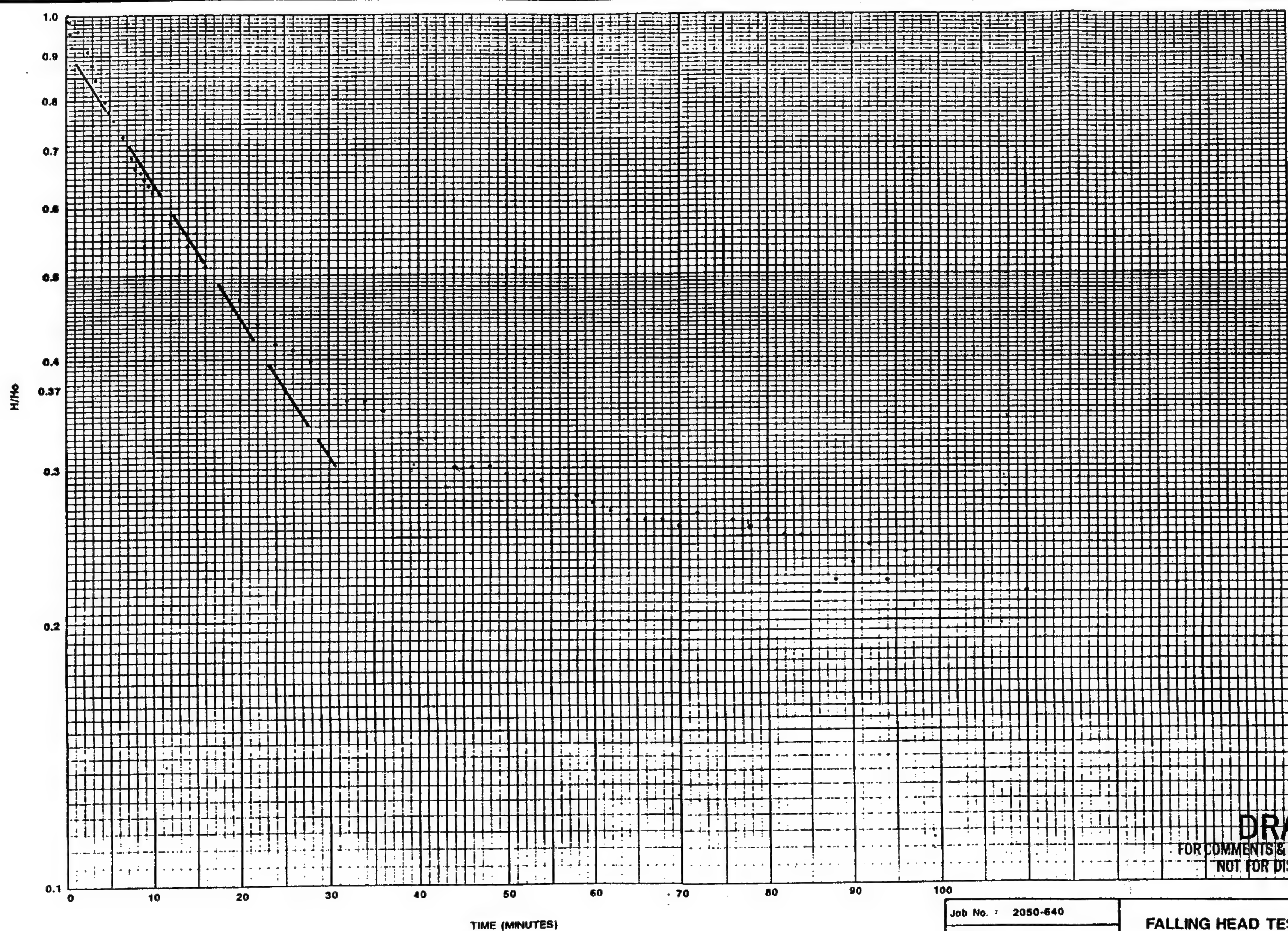
Job No. : 2050-64(	
Prepared by: R.L.C.	
Date: 8/23/90	

FALLING HEAD TEST: HVORSLEV
LSB-15



Job No. : 2050-640	RISING HEAD TEST: HVORSLEV LSB-15
Prepared by : R.L.C.	
Date : 8/22/90	

Woodward-Clyde Consultants

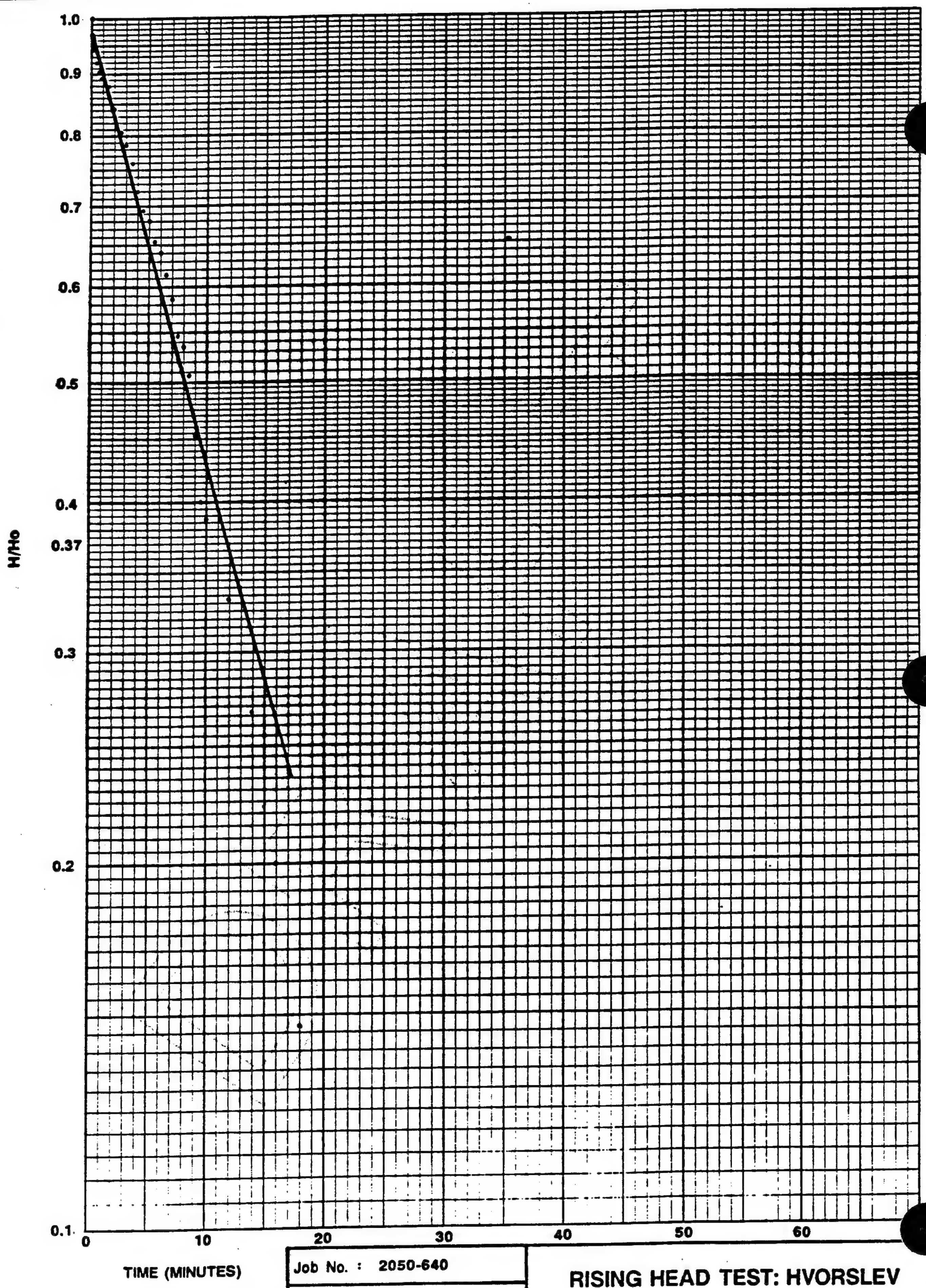


DRAFT
FOR COMMENTS & DISCUSSION ONLY
NOT FOR DISTRIBUTION

Job No. : 2050-640	FALLING HEAD TEST: HVORSLEV
Prepared by : R.L.C.	LSB-34
Date : 8/23/90	

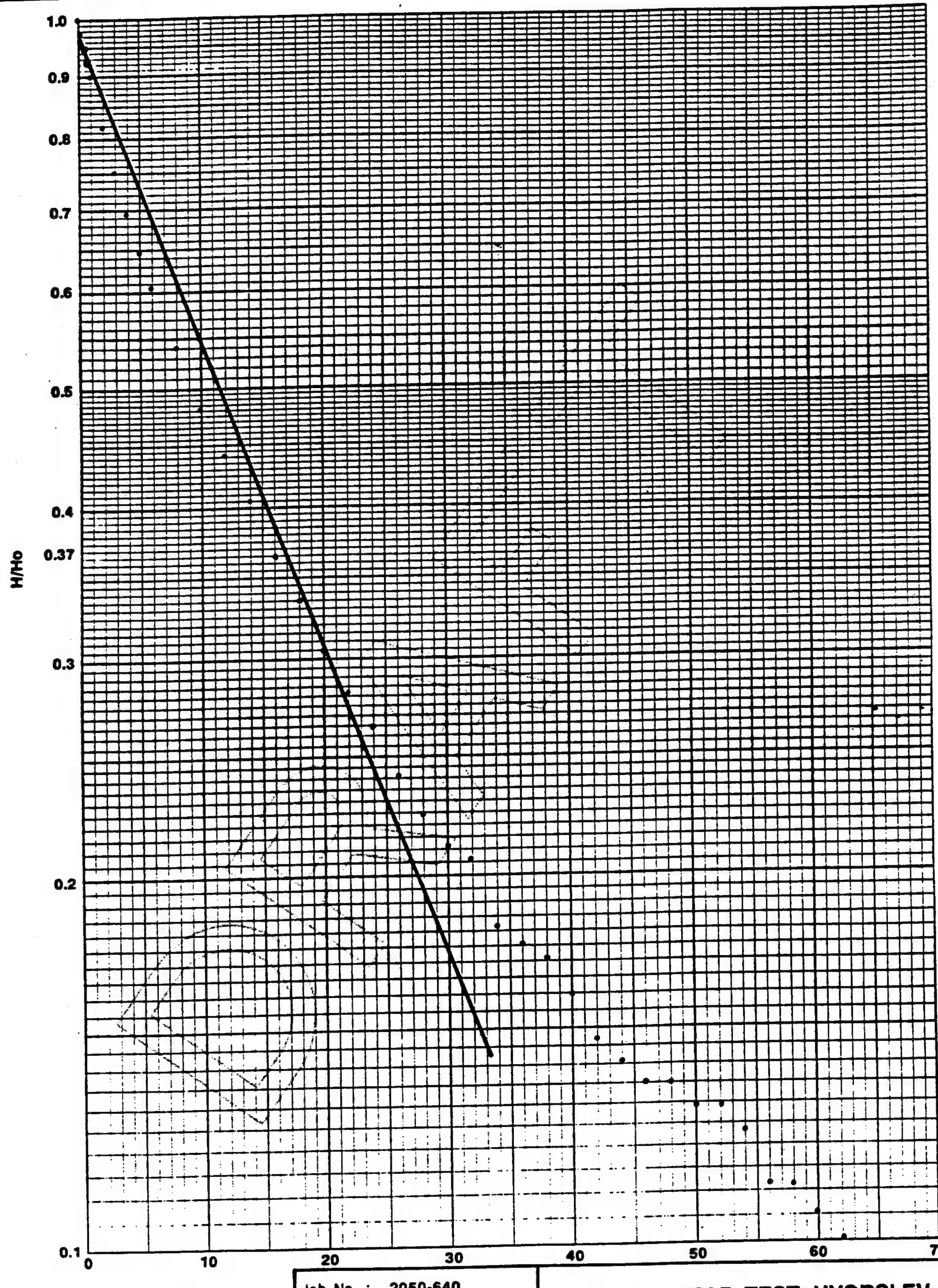
FIG.

124835

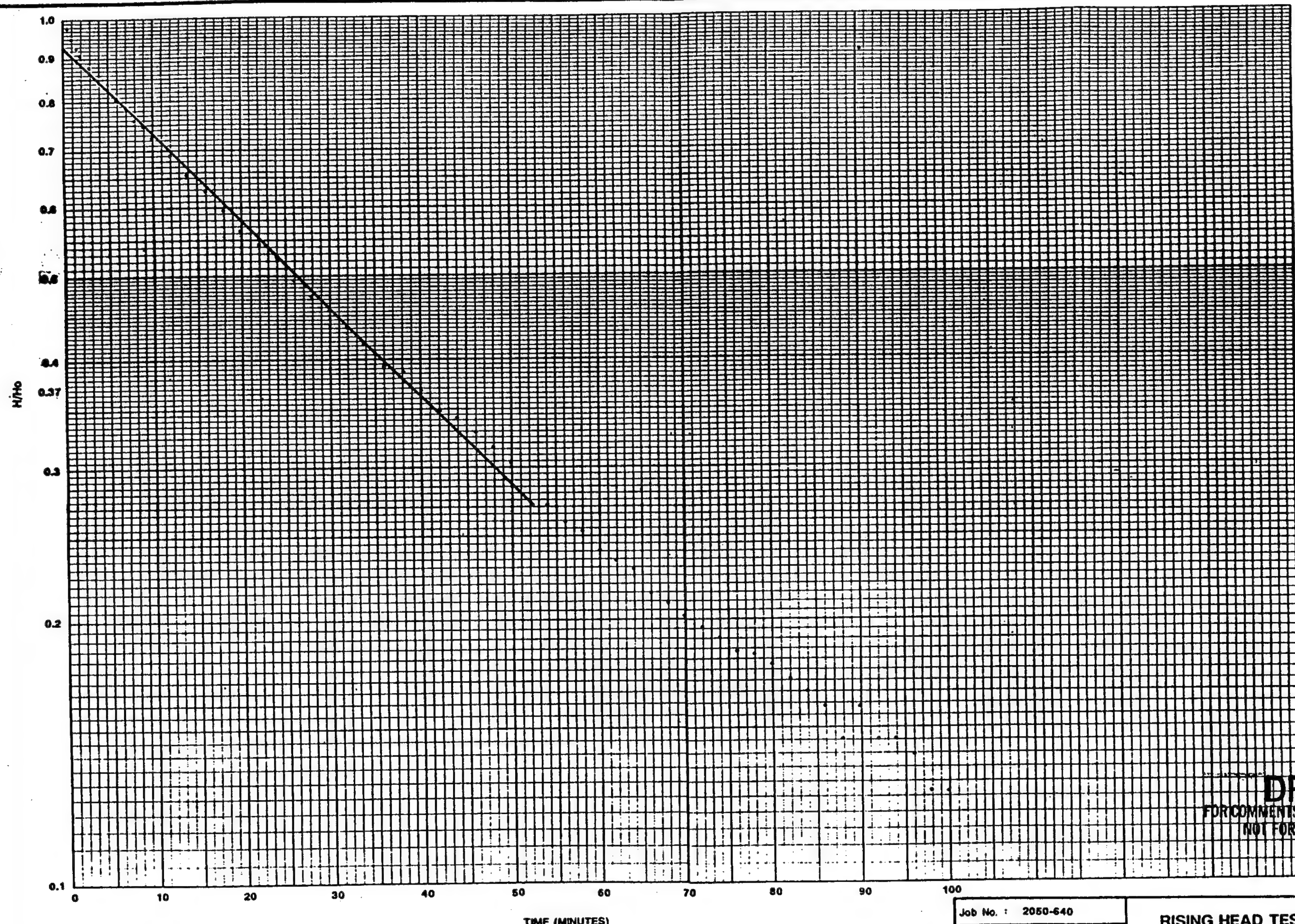


Job No. : 2050-640	
Prepared by : R.L.C.	
Date : 8/22/90	

RISING HEAD TEST: HVORSLEV
LSB-34



Job No. : 2050-640	FALLING HEAD TEST: HVORSLEV
Prepared by : R.L.C.	LSB-35
Date : 8/22/90	

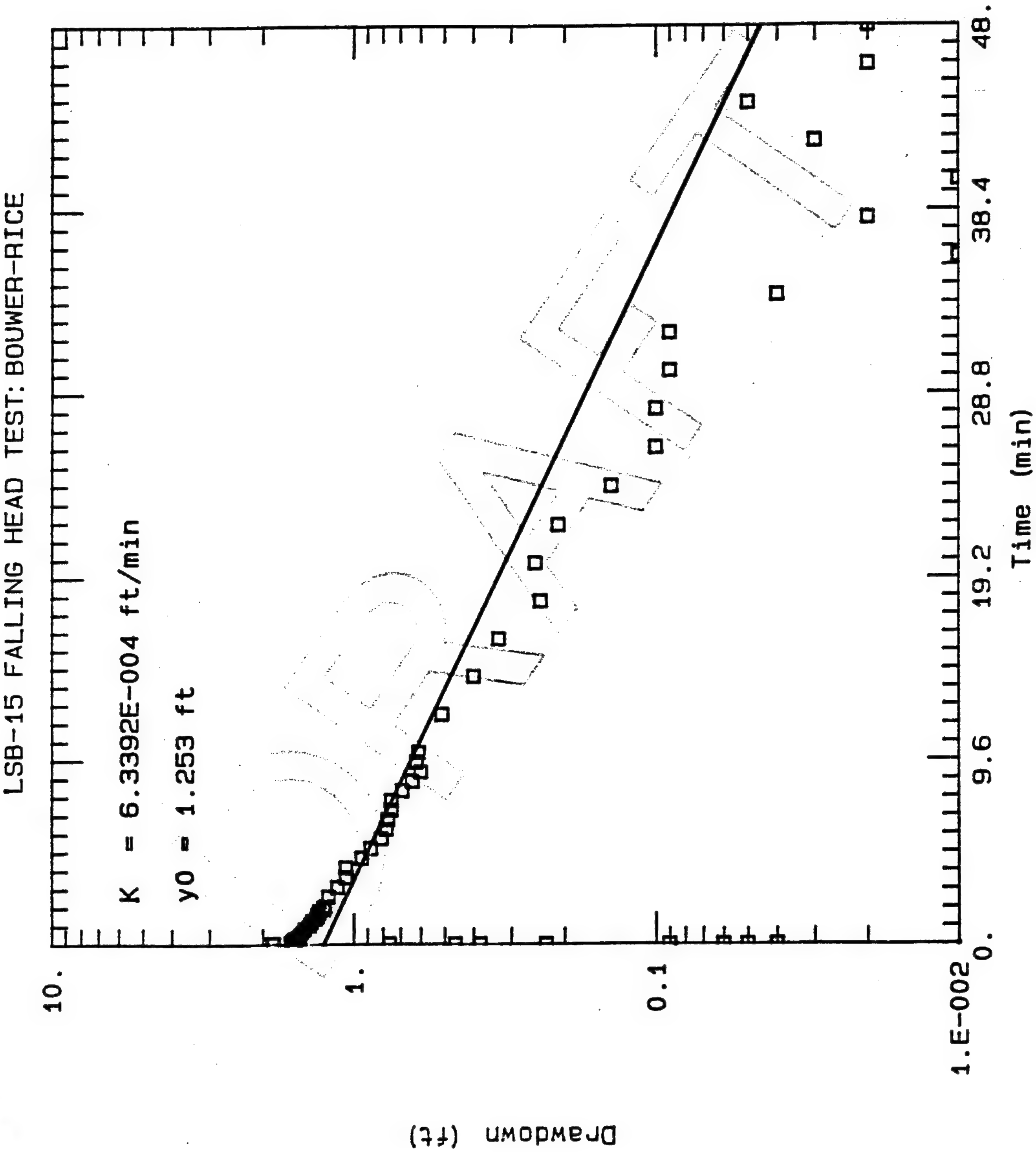


DRAFT
FOR COMMENTS & DISCUSSION ONLY
NOT FOR DISTRIBUTION

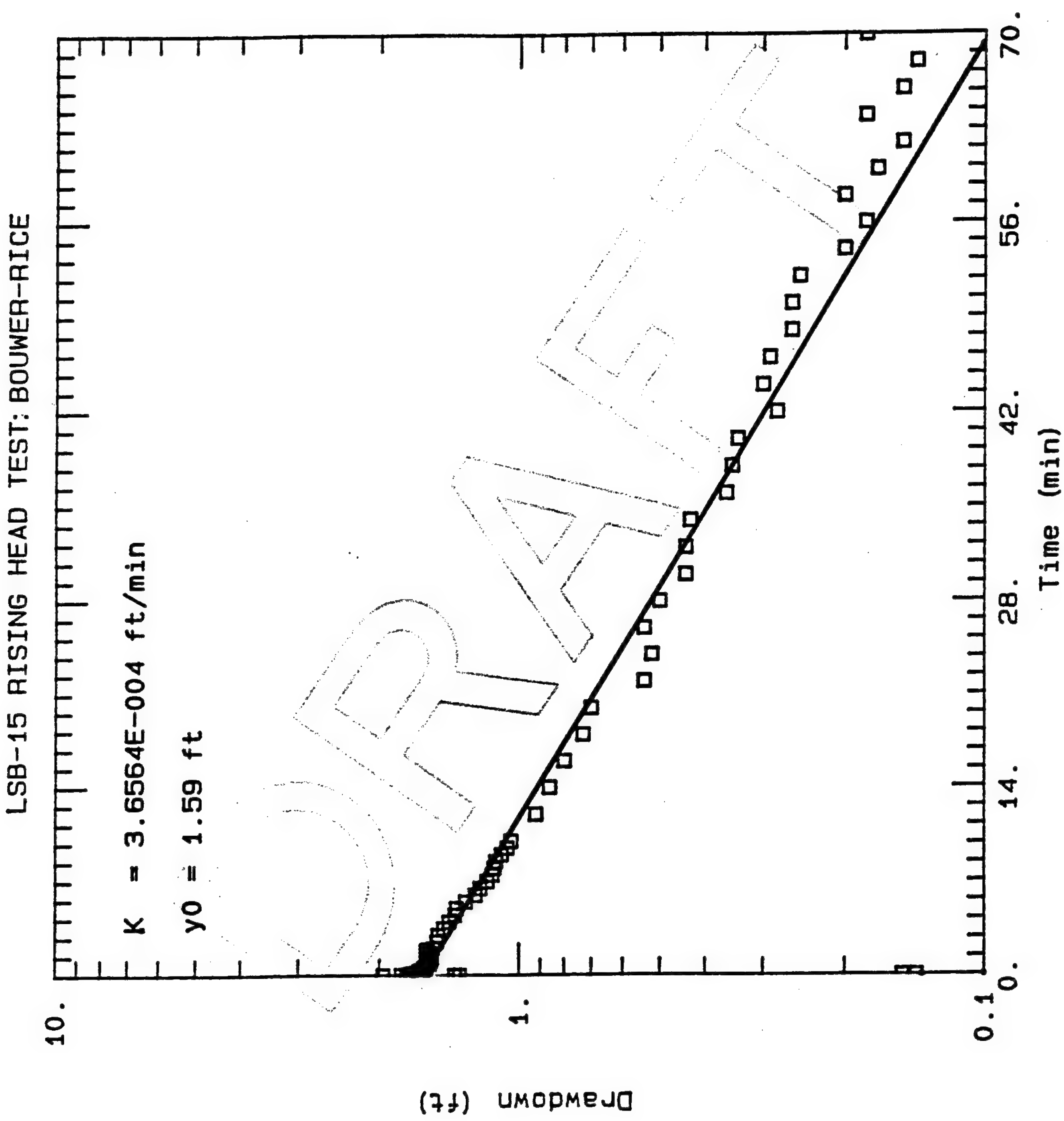
Job No. : 2050-640	RISING HEAD TEST: HVORSLEV
Prepared by : R.L.C.	LSB-35
Date : 8/23/90	

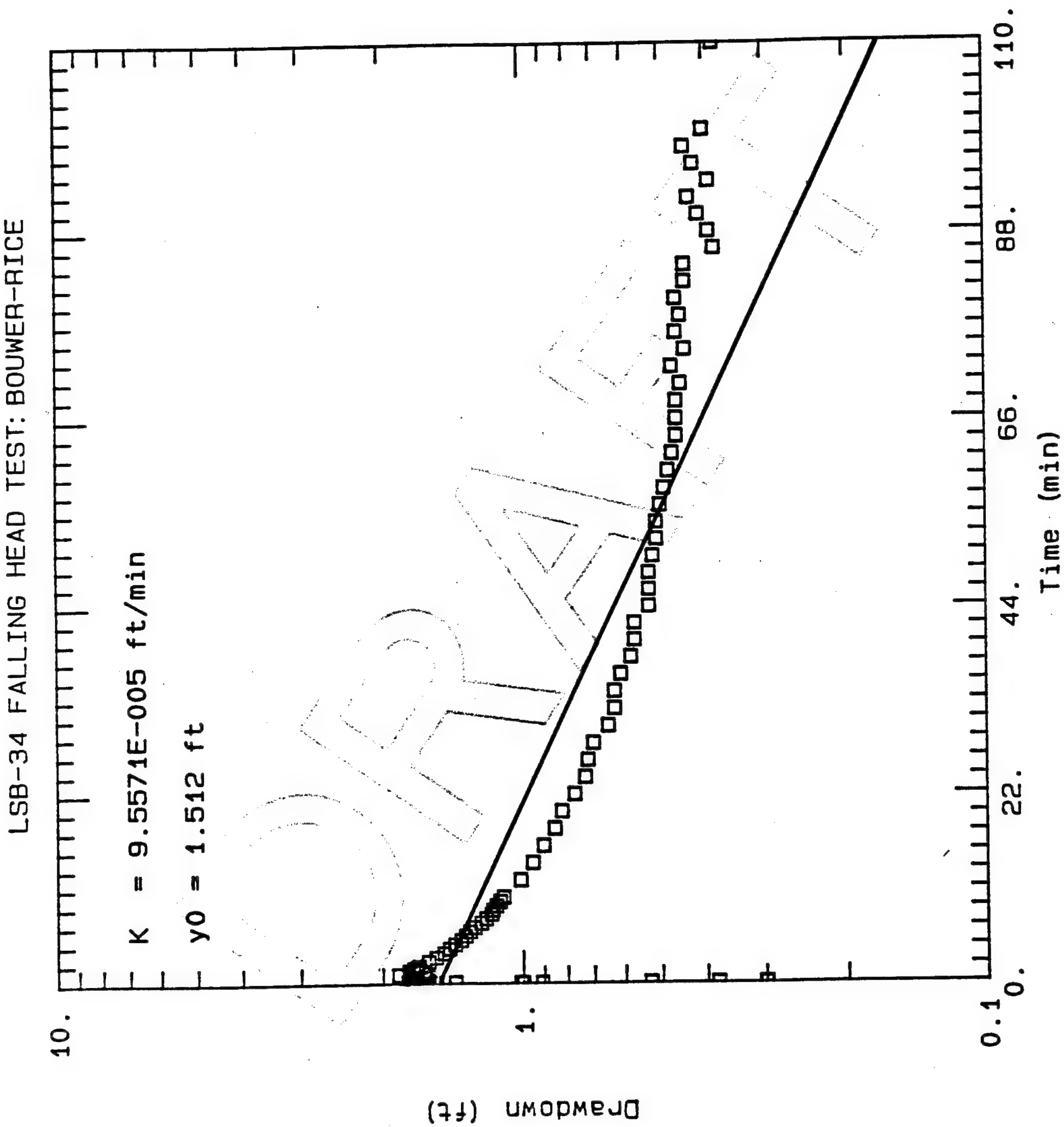
FIG.

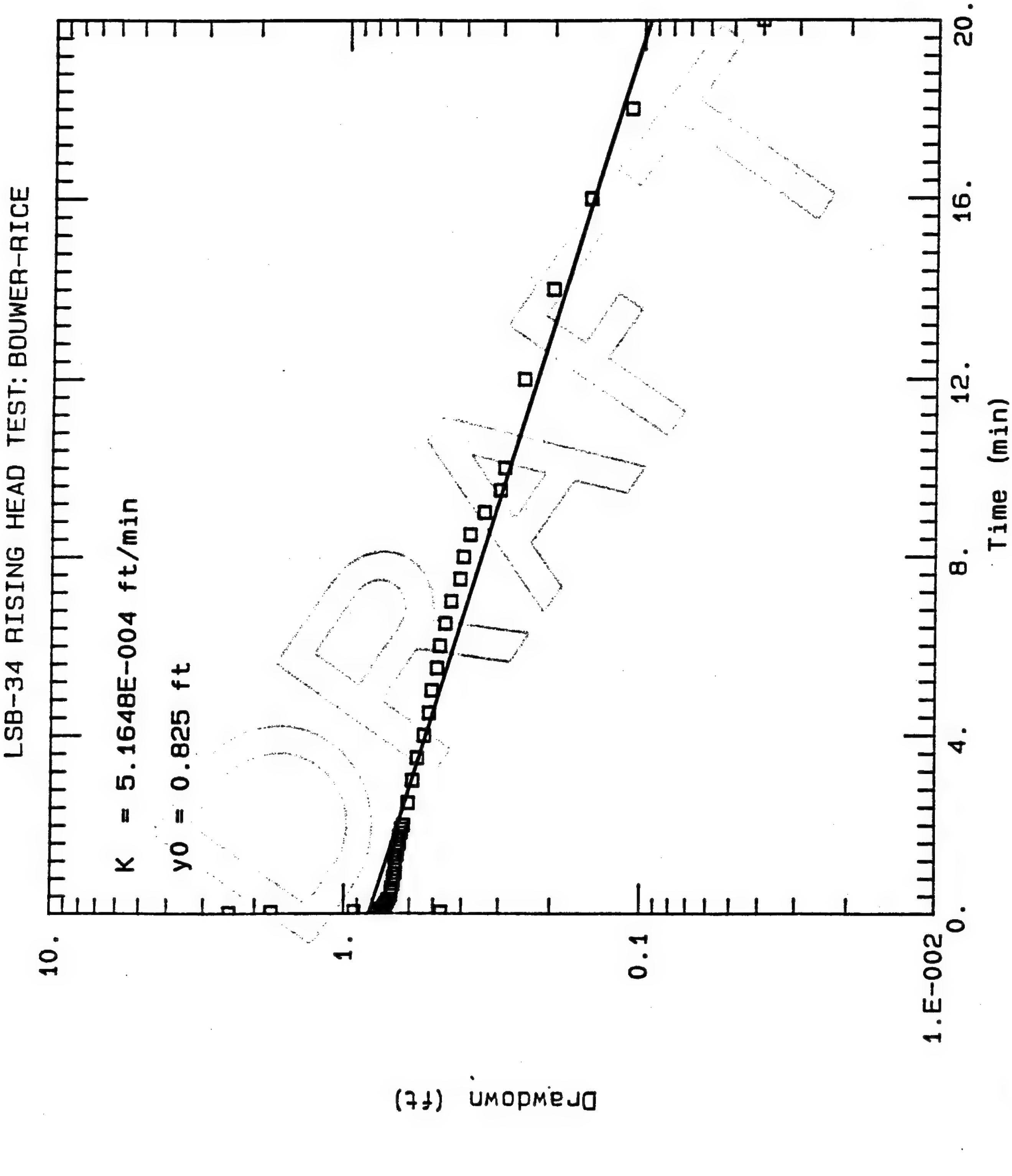
124835

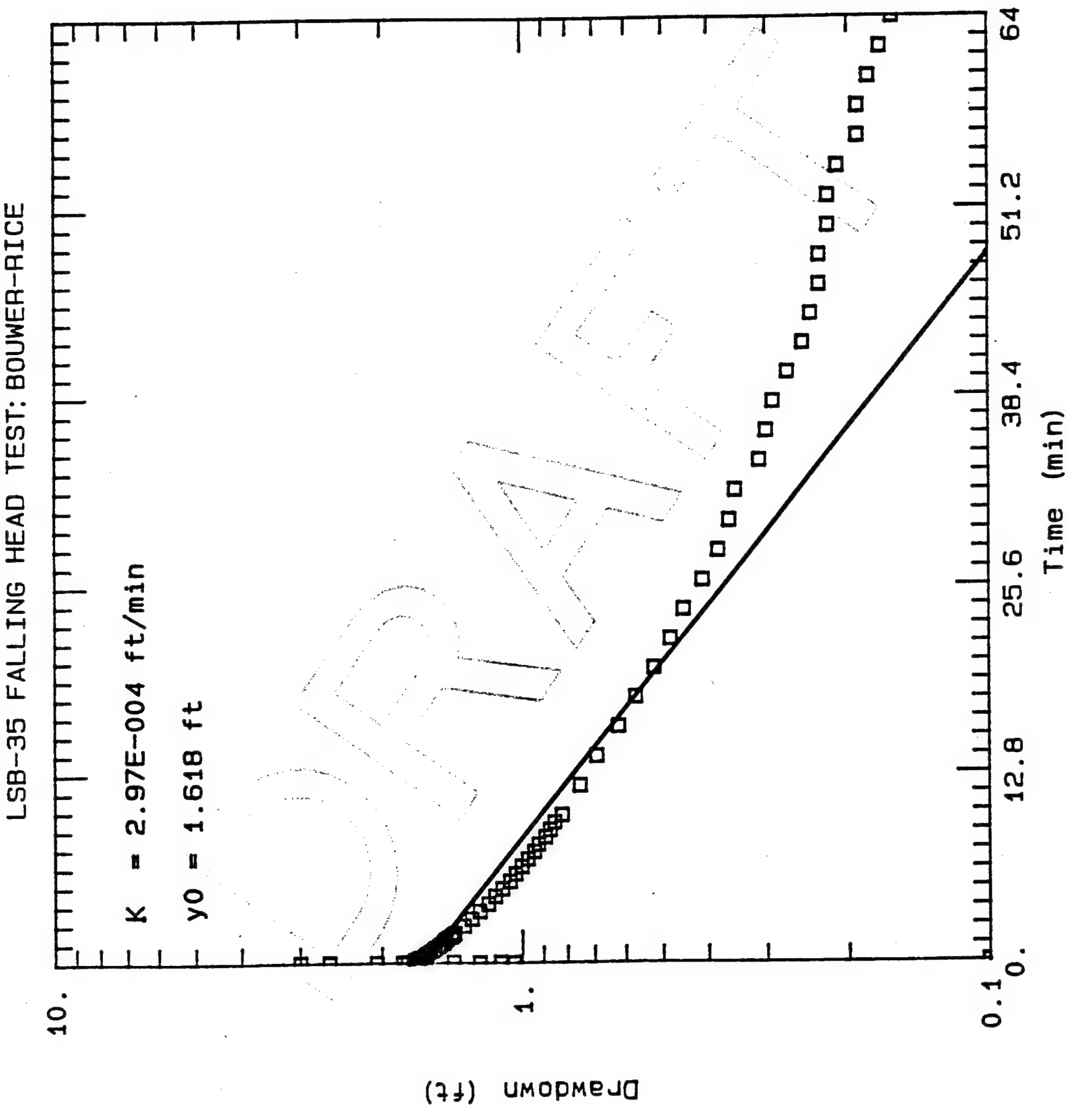


LSB-15 FALLING HEAD TEST: BOUWER-RICE
K = 6.3392E-004 ft/min
y0 = 1.253 ft
Drawdown (ft)
10.
1.
0.1
1.E-002
Time (min)
0.
9.6
19.2
28.8
38.4
48.

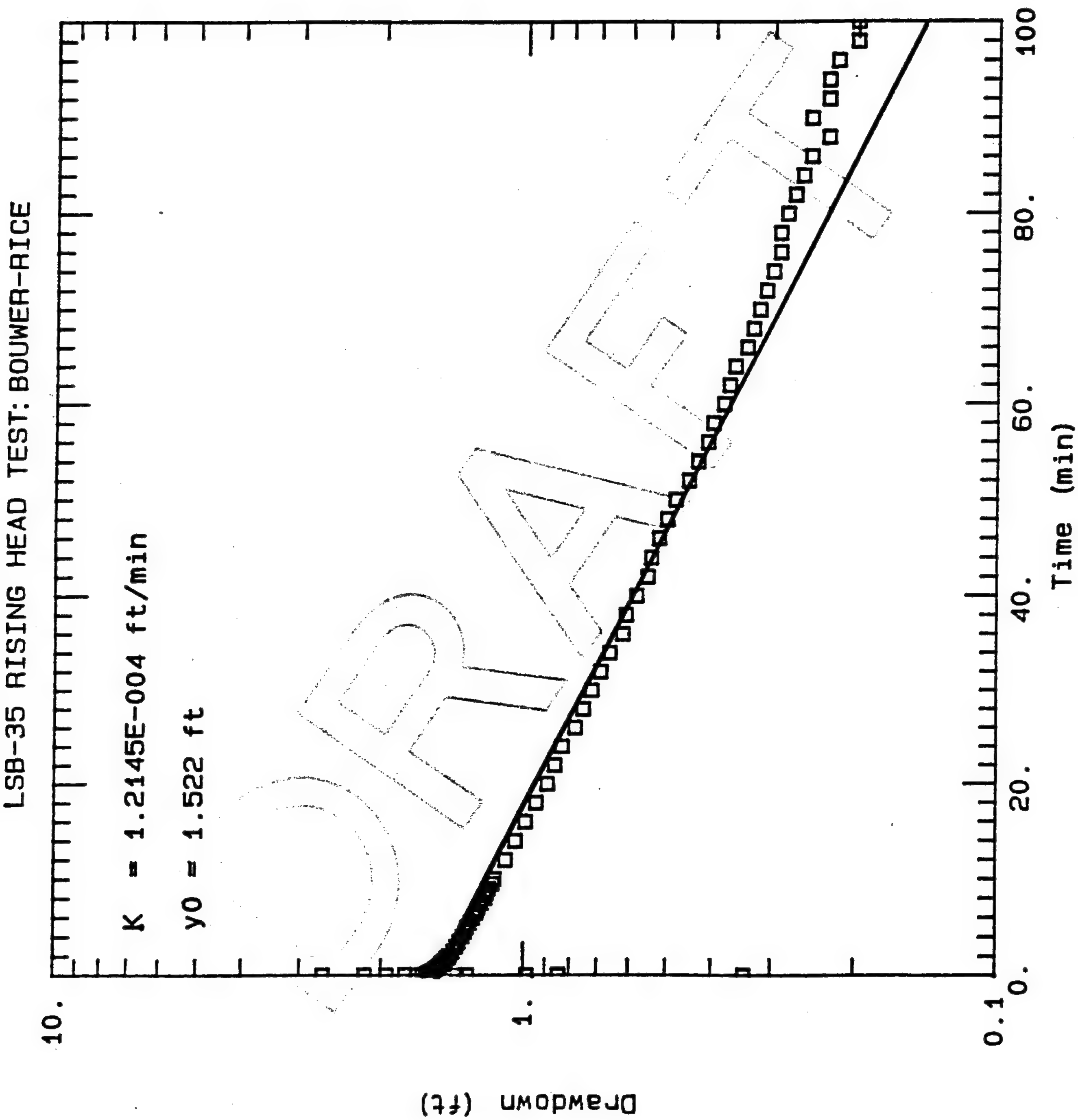

LSB-15 RISING HEAD TEST: BOUWER-RICE
K = 3.6564E-004 ft/min
y0 = 1.59 ft
Drawdown (ft)
10.
1.
0.1
Time (min)
0.
14.
28.
42.
56.
70.


LSB-34 FALLING HEAD TEST: BOUWER-RICE
K = 9.5571E-005 ft/min
y0 = 1.512 ft
Drawdown (ft)
10.
1.
0.1
0.
22.
44.
66.
88.
110.
Time (min)


LSB-34 RISING HEAD TEST: BOUWER-RICE
K = 5.1648E-004 ft/min
y0 = 0.825 ft
Time (min)
Drawdown (ft)
0.
4.
8.
12.
16.
20.
10.
1.
0.1
1.E-002



LSB-35 FALLING HEAD TEST: BOUWER-RICE
K = 2.97E-004 ft/min
y0 = 1.618 ft
Drawdown (ft)
10.
1.
0.1
Time (min)
0.
12.8
25.6
38.4
51.2
64.
DRAFT


LSB-35 RISING HEAD TEST: BOUWER-RICE
K = 1.2145E-004 ft/min
y0 = 1.522 ft
Drawdown (ft)
Time (min)
10.
1.
0.1
0.
20.
40.
60.
80.
100.
DRAFT

SLUG TEST DATA FORM

Location RMA

Borehole No. LSB-15

Test Date 7/23/90

Measuring Point toc

Type of Test Falling/Rising head

Transductor Probe Serial No. 02813

Datalogger Test Run No. 1
(include time and date for identification purposes)

Name Andre Fiedler

Groundwater Elevation Before Test 11.1 btoc

Total Casing Depth 23.2 ft (26.75 btoc)

Borehole Diameter 10 in

Casing Diameter 4 in

Screened Interval 18.2 - 23.2

Sand Pack Interval 13 - 23.2

Lithology Tested clay, sandy

SF = 10.12
off = 0.002

step 0 Falling head
step 1 Rising head

transducer depth = 23.11 btoc
transducer = 12.01 below swl

Slug depth (bottom) = 16.5 ft btoc

TABLE 5
SLUG TEST DATA LSB-15

LSB-15 Falling Head Test			LSB-15 Rising Head Test		
Time(min)	Head Change(ft)	Head Ratio	Time(min)	Head Change(ft)	Head Ratio
0	-0.07		0	1.61	
0.0033	-0.09		0.0033	0.14	
0.0066	-0.06		0.0066	0.15	
0.0099	-0.04		0.0099	1.37	
0.0133	-0.05		0.0133	1.34	
0.0166	-0.04		0.0166	1.96	
0.02	-0.06		0.02	1.7	
0.0233	-0.23		0.0233	1.79	
0.0266	-0.38		0.0266	1.74	
0.03	-0.46		0.03	1.74	
0.0333	-0.76		0.0333	1.7	
0.05	-1.86		0.05	1.7	
0.0666	-1.54		0.0666	1.69	
0.0833	-1.83		0.0833	1.71	
0.1	-1.5		0.1	1.71	
0.1166	-1.62		0.1166	1.69	
0.1333	-1.59		0.1333	1.65	
0.15	-1.58		0.15	1.66	
0.1666	-1.58		0.1666	1.66	
0.1833	-1.57		0.1833	1.61	
0.2	-1.59	1.000	0.2	1.62	
0.2166	-1.58	0.994	0.2166	1.64	1.000
0.2333	-1.58	0.994	0.2333	1.63	0.994
0.25	-1.55	0.975	0.25	1.63	0.994
0.2666	-1.56	0.981	0.2666	1.62	0.988
0.2833	-1.57	0.987	0.2833	1.62	0.988
0.3	-1.54	0.969	0.3	1.64	1.000
0.3166	-1.54	0.969	0.3166	1.63	0.994
0.3333	-1.55	0.975	0.3333	1.62	0.988
0.4167	-1.52	0.956	0.4167	1.6	0.976
0.5	-1.5	0.943	0.5	1.6	0.976
0.5833	-1.48	0.931	0.5833	1.6	0.976
0.6667	-1.47	0.925	0.6667	1.58	0.963
0.75	-1.44	0.906	0.75	1.58	0.963
0.8333	-1.45	0.912	0.8333	1.55	0.945
0.9167	-1.41	0.887	0.9167	1.58	0.963
1	-1.38	0.868	1	1.55	0.945
1.0833	-1.39	0.874	1.0833	1.54	0.939
1.1667	-1.37	0.862	1.1667	1.55	0.945
1.25	-1.37	0.862	1.25	1.54	0.939
1.3333	-1.33	0.836	1.3333	1.53	0.933
1.4166	-1.32	0.830	1.4166	1.57	0.957
1.5	-1.31	0.824	1.5	1.58	0.963
1.5833	-1.31	0.824	1.5833	1.56	0.951
1.6667	-1.29	0.811	1.6667	1.55	0.945
1.75	-1.3	0.818	1.75	1.57	0.957
1.8333	-1.25	0.786	1.8333	1.58	0.963
1.9167	-1.26	0.792	1.9167	1.57	0.957
2	-1.24	0.780	2	1.53	0.933
2.5	-1.21	0.761	2.5	1.5	0.915
3	-1.13	0.711	3	1.49	0.909
3.5	-1.06	0.667	3.5	1.45	0.884
4	-1.06	0.667	4	1.41	0.860
4.5	-0.94	0.591	4.5	1.37	0.835
5	-0.88	0.553	5	1.36	0.829
5.5	-0.81	0.509	5.5	1.3	0.793
6	-0.78	0.491	6	1.24	0.756
6.5	-0.77	0.484	6.5	1.21	0.738
7	-0.75	0.472	7	1.17	0.713
7.5	-0.75	0.472	7.5	1.14	0.695
8	-0.69	0.434	8	1.13	0.689
8.5	-0.64	0.403	8.5	1.12	0.683
9	-0.6	0.377	9	1.09	0.665
9.5	-0.62	0.390	9.5	1.06	0.646
10	-0.61	0.384	10	1.04	0.634
12	-0.51	0.321	12	0.92	0.561
14	-0.4	0.252	14	0.86	0.524
16	-0.33	0.208	16	0.8	0.488
18	-0.24	0.151	18	0.73	0.445
20	-0.25	0.157	20	0.7	0.427
22	-0.21	0.132	22	0.54	0.329
24	-0.14	0.088	24	0.52	0.317
26	-0.1	0.063	26	0.54	0.329

TABLE 5 (cont.)
SLUG TEST DATA LSB-15

LSB-15
Falling Head Test

Time(min)	Head Change(ft)	Head Ratio
28	-0.1	0.063
30	-0.09	0.057
32	-0.09	0.057
34	-0.04	0.025
36	-0.01	0.006
38	-0.02	0.013
40	-0.01	0.006
42	0.03	-0.019
44	0.05	-0.031
46	-0.02	0.013
48	-0.02	0.013

LSB-15
Rising Head Test

Time(min)	Head Change(ft)	Head Ratio
28	0.5	0.305
30	0.44	0.268
32	0.44	0.268
34	0.43	0.262
36	0.36	0.220
38	0.35	0.213
40	0.34	0.207
42	0.28	0.171
44	0.3	0.183
46	0.29	0.177
48	0.26	0.159
50	0.26	0.159
52	0.25	0.152
54	0.2	0.122
56	0.18	0.110
58	0.2	0.122
60	0.17	0.104
62	0.15	0.091
64	0.18	0.110
66	0.15	0.091
68	0.14	0.085
70	0.18	0.110

Woodward-Clyde Consultants

SLUG TEST DATA FORM

Location RMA

Name Andre Fiedler

Borehole No. LSB-34

Groundwater Elevation Before Test 14.75btoc

Test Date 7/24/90

Total Casing Depth 28.3 ft btoc

Measuring Point toc

Borehole Diameter 10 in

Type of Test Falling/Rising head

Casing Diameter 4 in

Transductor Probe Serial No. 02813

Screened Interval 18 - 28 ft

Datalogger Test Run No. 2
(include time and date for identification purposes)

Sand Pack Interval 15.4 - 28.4 ft

Lithology Tested sand, silty to clay and sand

SF = 10.12 step 0 Falling head
off = 0.002 step 1 Rising head

transducer depth = 26 ft btoc
Slug depth (bottom) = 20 ft btoc
Δs_o = 12.01 below swl

TABLE 6
SLUG TEST DATA LSB-34

LSB-34 Falling Head Test			LSB-34 Rising Head Test		
Time(min)	Head Change(ft)	Head Ratio	Time(min)	Head Change(ft)	Head Ratio
0	0		0	-1.06	
0.0033	0		0.0033	-1.06	
0.0066	0		0.0066	-1.06	
0.0099	-0.3		0.0099	-1.15	
0.0133	-0.3		0.0133	2.44	
0.0166	-0.53		0.0166	-0.28	
0.02	-0.91		0.02	-1.79	
0.0233	-0.38		0.0233	-0.02	
0.0266	-1.01		0.0266	-0.64	
0.03	-1		0.03	1.76	
0.0333	-1.75		0.0333	0.47	
0.05	-1.73		0.05	0.92	
0.0666	-1.54		0.0666	0.72	
0.0833	-1.4		0.0833	0.75	1.000
0.1	-1.73		0.1	0.75	1.000
0.1166	-1.77		0.1166	0.74	0.987
0.1333	-1.74		0.1333	0.73	0.973
0.15	-1.71		0.15	0.73	0.973
0.1666	-1.76	1.000	0.1666	0.73	0.973
0.1833	-1.75	0.994	0.1833	0.72	0.960
0.2	-1.74	0.989	0.2	0.72	0.960
0.2166	-1.74	0.989	0.2166	0.72	0.960
0.2333	-1.73	0.983	0.2333	0.72	0.960
0.25	-1.73	0.983	0.25	0.71	0.947
0.2666	-1.72	0.977	0.2666	0.71	0.947
0.2833	-1.72	0.977	0.2833	0.71	0.947
0.3	-1.72	0.977	0.3	0.71	0.947
0.3166	-1.71	0.972	0.3166	0.71	0.947
0.3333	-1.71	0.972	0.3333	0.7	0.933
0.4167	-1.7	0.966	0.4167	0.69	0.920
0.5	-1.68	0.955	0.5	0.69	0.920
0.5833	-1.65	0.938	0.5833	0.69	0.920
0.6667	-1.63	0.926	0.6667	0.68	0.907
0.75	-1.62	0.920	0.75	0.68	0.907
0.8333	-1.6	0.909	0.8333	0.68	0.907
0.9167	-1.73	0.983	0.9167	0.67	0.893
1	-1.85	1.051	1	0.67	0.893
1.0833	-1.6	0.909	1.0833	0.67	0.893
1.1667	-1.64	0.932	1.1667	0.67	0.893
1.25	-1.63	0.926	1.25	0.67	0.893
1.3333	-1.65	0.938	1.3333	0.66	0.880
1.4166	-1.76	1.000	1.4166	0.66	0.880
1.5	-1.69	0.960	1.5	0.66	0.880
1.5833	-1.72	0.977	1.5833	0.65	0.867
1.6667	-1.72	0.977	1.6667	0.65	0.867
1.75	-1.7	0.966	1.75	0.65	0.867
1.8333	-1.69	0.960	1.8333	0.64	0.853
1.9167	-1.68	0.955	1.9167	0.64	0.853
2	-1.67	0.949	2	0.63	0.840
2.5	-1.6	0.909	2.5	0.61	0.813
3	-1.54	0.875	3	0.59	0.787
3.5	-1.48	0.841	3.5	0.57	0.760
4	-1.44	0.818	4	0.54	0.720
4.5	-1.4	0.795	4.5	0.52	0.693
5	-1.36	0.773	5	0.51	0.680
5.5	-1.33	0.756	5.5	0.49	0.653
6	-1.3	0.739	6	0.48	0.640
6.5	-1.27	0.722	6.5	0.46	0.613
7	-1.23	0.699	7	0.44	0.587
7.5	-1.2	0.682	7.5	0.41	0.547
8	-1.17	0.665	8	0.4	0.533
8.5	-1.16	0.659	8.5	0.38	0.507
9	-1.14	0.648	9	0.34	0.453
9.5	-1.12	0.636	9.5	0.3	0.400
10	-1.1	0.625	10	0.29	0.387
12	-1.01	0.574	12	0.25	0.333
14	-0.95	0.540	14	0.2	0.267
16	-0.9	0.511	16	0.15	0.200
18	-0.85	0.483	18	0.11	0.147
20	-0.82	0.466	20	0.04	0.053
22	-0.77	0.438	22	0	0.000
24	-0.73	0.415	24	-0.06	-0.080
26	-0.72	0.409	26	-0.09	-0.120

TABLE 6 (cont.)
SLUG TEST DATA LSB-34

LSB-34
Falling Head Test

Time(min)	Head Change(ft)	Head Ratio
28	-0.7	0.398
30	-0.65	0.369
32	-0.63	0.358
34	-0.63	0.358
36	-0.61	0.347
38	-0.58	0.330
40	-0.57	0.324
42	-0.57	0.324
44	-0.53	0.301
46	-0.53	0.301
48	-0.53	0.301
50	-0.52	0.295
52	-0.51	0.290
54	-0.51	0.290
56	-0.5	0.284
58	-0.49	0.278
60	-0.48	0.273
62	-0.47	0.267
64	-0.46	0.261
66	-0.46	0.261
68	-0.46	0.261
70	-0.45	0.256
72	-0.47	0.267
74	-0.44	0.250
76	-0.46	0.261
78	-0.45	0.256
80	-0.46	0.261
82	-0.44	0.250
84	-0.44	0.250
86	-0.38	0.216
88	-0.39	0.222
90	-0.41	0.233
92	-0.43	0.244
94	-0.39	0.222
96	-0.42	0.239
98	-0.44	0.250
100	-0.4	0.227
110	-0.38	0.216

LSB-34
Rising Head Test

Time(min)	Head Change(ft)	Head Ratio
28	-0.15	-0.200
30	-0.18	-0.240
32	-0.22	-0.293
34	-0.25	-0.333
36	-0.3	-0.400
38	-0.31	-0.413
40	-0.34	-0.453
42	-0.39	-0.520
44	-0.42	-0.560
46	-0.43	-0.573
48	-0.47	-0.627
50	-0.49	-0.653

Woodward-Clyde Consultants

SLUG TEST DATA FORM

Location RMA

Borehole No. LSB-35

Test Date 7/23/90

Measuring Point toc

Type of Test Falling/Rising head

Transductor Probe Serial No. 02813

Datalogger Test Run No. 0
(include time and date for
identification purposes)

Name Andre Fiedler

Groundwater Elevation Before Test 10.25btoc

Total Casing Depth 30.2 ft btoc

Borehole Diameter 10 in

Casing Diameter 4 in

Screened Interval 19.9 - 29.9 ft

Sand Pack Interval 14 - 31 ft

Lithology Tested clay, verry sandy to clay
silty sandy

SF = 10.12 step 0 Falling head
off = 0.002 step 1 Rising head

transducer depth = 25 ft btoc Slug depth (bottom) = 16.5 ft btoc
Δs_0 = 13.85 below swl

TABLE 7
SLUG TEST DATA LSB-35

	LSB-35 Falling Head Test			LSB-35 Rising Head Test	
Time(min)	Head Change(ft)	Head Ratio	Time(min)	Head Change(ft)	Head Ratio
0	-2.32		0	1.04	
0.0033	-1.8		0.0033	0.98	
0.0066	-1.04		0.0066	-0.48	
0.0099	-1.7		0.0099	0.34	
0.0133	-2.59		0.0133	2.66	
0.0166	-1.23		0.0166	1.94	
0.02	-0.1		0.02	0.84	
0.0233	-2.05		0.0233	1.67	
0.0266	-2.99		0.0266	2.16	
0.03	-1.71		0.03	1.37	
0.0333	-1.76		0.0333	1.31	
0.05	-1.11		0.05	1.77	
0.0666	-1.4		0.0666	1.52	
0.0833	-1.61		0.0833	1.63	
0.1	-1.7	1.000	0.1	1.58	
0.1166	-1.7	1.000	0.1166	1.6	
0.1333	-1.7	1.000	0.1333	1.58	1.000
0.15	-1.69	0.994	0.15	1.58	1.000
0.1666	-1.66	0.976	0.1666	1.58	1.000
0.1833	-1.67	0.982	0.1833	1.58	1.000
0.2	-1.67	0.982	0.2	1.57	0.994
0.2166	-1.67	0.982	0.2166	1.57	0.994
0.2333	-1.66	0.976	0.2333	1.57	0.994
0.25	-1.66	0.976	0.25	1.57	0.994
0.2666	-1.65	0.971	0.2666	1.56	0.987
0.2833	-1.65	0.971	0.2833	1.56	0.987
0.3	-1.65	0.971	0.3	1.56	0.987
0.3166	-1.64	0.965	0.3166	1.56	0.987
0.3333	-1.64	0.965	0.3333	1.55	0.981
0.4167	-1.62	0.953	0.4167	1.55	0.981
0.5	-1.61	0.947	0.5	1.54	0.975
0.5833	-1.6	0.941	0.5833	1.53	0.968
0.6667	-1.58	0.929	0.6667	1.53	0.968
0.75	-1.57	0.924	0.75	1.52	0.962
0.8333	-1.55	0.912	0.8333	1.51	0.956
0.9167	-1.54	0.906	0.9167	1.5	0.949
1	-1.53	0.900	1	1.5	0.949
1.0833	-1.51	0.888	1.0833	1.49	0.943
1.1667	-1.5	0.882	1.1667	1.48	0.937
1.25	-1.49	0.876	1.25	1.48	0.937
1.3333	-1.47	0.865	1.3333	1.47	0.930
1.4166	-1.47	0.865	1.4166	1.47	0.930
1.5	-1.46	0.859	1.5	1.46	0.924
1.5833	-1.45	0.853	1.5833	1.45	0.918
1.6667	-1.44	0.847	1.6667	1.45	0.918
1.75	-1.42	0.835	1.75	1.44	0.911
1.8333	-1.41	0.829	1.8333	1.44	0.911
1.9167	-1.4	0.824	1.9167	1.43	0.905
2	-1.39	0.818	2	1.43	0.905
2.5	-1.33	0.782	2.5	1.4	0.886
3	-1.28	0.753	3	1.38	0.873
3.5	-1.23	0.724	3.5	1.36	0.861
4	-1.18	0.694	4	1.34	0.848
4.5	-1.14	0.671	4.5	1.32	0.835
5	-1.1	0.647	5	1.31	0.829
5.5	-1.06	0.624	5.5	1.29	0.816
6	-1.03	0.606	6	1.27	0.804
6.5	-1	0.588	6.5	1.25	0.791
7	-0.97	0.571	7	1.24	0.785
7.5	-0.94	0.553	7.5	1.22	0.772
8	-0.92	0.541	8	1.2	0.759
8.5	-0.89	0.524	8.5	1.19	0.753
9	-0.87	0.512	9	1.18	0.747
9.5	-0.85	0.500	9.5	1.16	0.734
10	-0.82	0.482	10	1.15	0.728
12	-0.75	0.441	12	1.09	0.690
14	-0.69	0.406	14	1.04	0.658
16	-0.62	0.365	16	0.99	0.627
18	-0.57	0.335	18	0.94	0.595
20	-0.52	0.306	20	0.89	0.563
22	-0.48	0.282	22	0.86	0.544
24	-0.45	0.265	24	0.83	0.525
26	-0.41	0.241	26	0.78	0.494

TABLE 7 (cont.)
SLUG TEST DATA LSB-35

LSB-35
Falling Head Test

Time(min)	Head Change(ft)	Head Ratio
28	-0.38	0.224
30	-0.36	0.212
32	-0.35	0.206
34	-0.31	0.182
36	-0.3	0.176
38	-0.29	0.171
40	-0.27	0.159
42	-0.25	0.147
44	-0.24	0.141
46	-0.23	0.135
48	-0.23	0.135
50	-0.22	0.129
52	-0.22	0.129
54	-0.21	0.124
56	-0.19	0.112
58	-0.19	0.112
60	-0.18	0.106
62	-0.17	0.100
64	-0.16	0.094

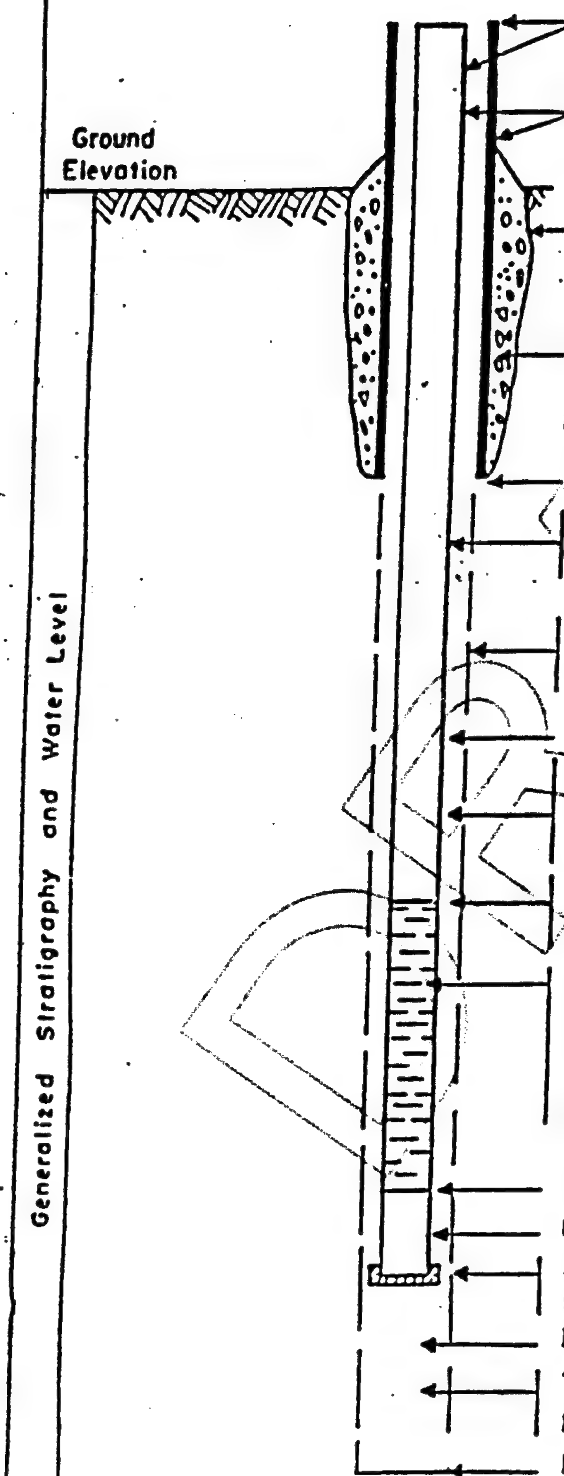
LSB-35
Rising Head Test

Time(min)	Head Change(ft)	Head Ratio
28	0.75	0.475
30	0.72	0.456
32	0.69	0.437
34	0.66	0.418
36	0.62	0.392
38	0.61	0.386
40	0.58	0.367
42	0.55	0.348
44	0.54	0.342
46	0.52	0.329
48	0.5	0.316
50	0.48	0.304
52	0.45	0.285
54	0.43	0.272
56	0.41	0.259
58	0.4	0.253
60	0.38	0.241
62	0.37	0.234
64	0.36	0.228
66	0.34	0.215
68	0.33	0.209
70	0.32	0.203
72	0.31	0.196
74	0.3	0.190
76	0.29	0.184
78	0.29	0.184
80	0.28	0.177
82	0.27	0.171
84	0.26	0.165
86	0.25	0.158
88	0.23	0.146
90	0.25	0.158
92	0.23	0.146
94	0.23	0.146
96	0.22	0.139
98	0.2	0.127
100	0.2	0.127

FIGURE 2 - WELL CONSTRUCTION FORM Well 36195

GROUND WATER OBSERVATION WELL REPORT

PROJECT RMA COE 89MC114A	Page 1 of 1
LOCATION Sec 36	Well No. LSB-15
Date Completed 6-25-90 Original Depth	Aquifer Alluvial
Inspected By T. Terry Date 6-28-90	
Checked By Date	Depth Interval



Elevation of top of surface casing / riser pipe. ______

Height of top of surface casing / riser pipe above ground surface 18 in

Depth of surface seal below ground surface NA

Type of surface seal: NA

I.D. of surface casing. NA

Type of surface casing: NA

Depth of surface casing below ground NA

I.D. of riser pipe. 4 in

Type of riser pipe: ~~4 in~~ PVC

Diameter of borehole 10 in

Depth of borehole 40

Type of backfill: Bentonite Slurry

Elev./depth top of seal. 11.5

Type of seal: bentonite

Elev./depth bottom of seal. 13.0

Type of sand pack. 10-20 sand

Depth of top of sand pack. 13.0

Elev./depth top of screened section. 18.2

Type of screened section: PVC

Describe openings 10 slot

I.D. of screened section. 4 in

Elev./depth bottom of screened section. 23.2

Length of blank section. 0.3

Elev./depth bottom of plugged blank section. 23.2

Elev./depth bottom of sand column. 23.2

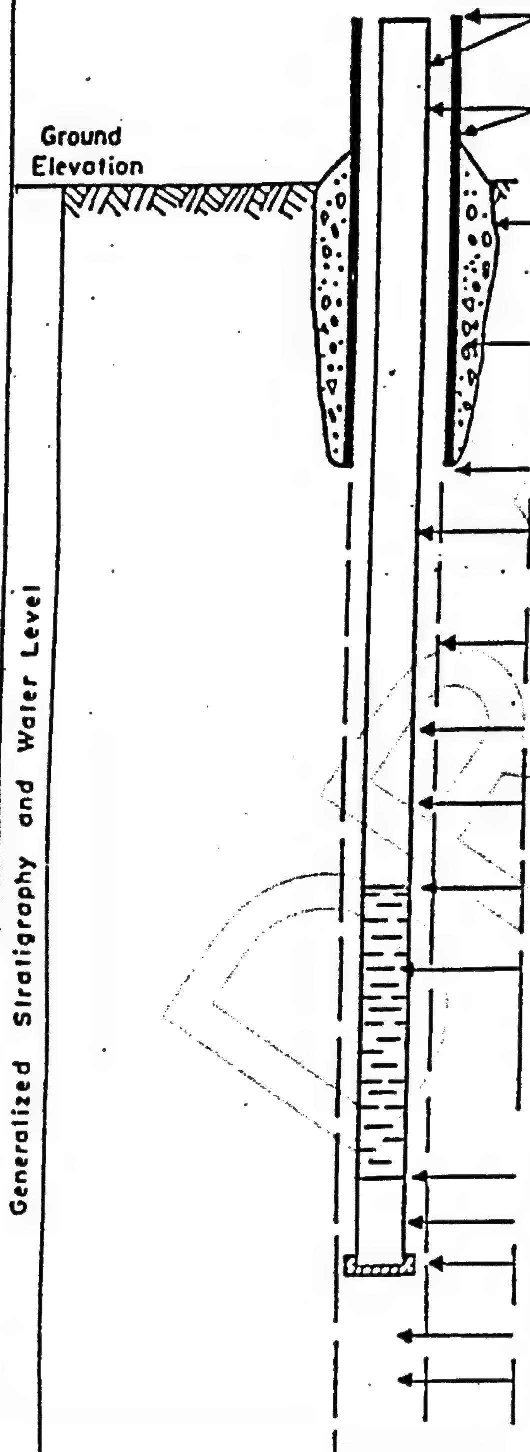
Type of backfill below observation pipe. ~~Sand~~ Grout

Elev./depth of hole. 40

FIGURE 2 - WELL CONSTRUCTION FORM Well 36196

GROUND WATER OBSERVATION WELL REPORT

PROJECT RMA COE 89MC114A	Page 1 of 1
LOCATION Sec. 36	Well No. LSB-34
Date Completed 6-27-90 Original Depth 28.4	Aquifer Alluvial
Inspected By T. Terry Date 6-27-90	
Checked By ______ Date ______	Depth Interval ______



Item	Value
Elevation of top of surface casing / riser pipe.	
Height of top of surface casing / riser pipe above ground surface	2.7
Depth of surface seal below ground surface	11.0
Type of surface seal: bentonite slurry	
I.D. of surface casing.	NA
Type of surface casing: NA	
Depth of surface casing below ground	NA
I.D. of riser pipe.	4in
Type of riser pipe: PVC	
Diameter of borehole	10 in
Depth of borehole	46
Type of backfill: bentonite slurry	
Elev./depth top of seal.	11.0
Type of seal: bentonite	
Elev./depth bottom of seal.	15.4
Type of sand pack. 10-20 sand	
Depth of top of sand pack.	15.4
Elev./depth top of screened section.	18
Type of screened section: PVC	
Describe openings 10 slot	
I.D. of screened section.	4in
Elev./depth bottom of screened section.	28
Length of blank section.	0.3
Elev./depth bottom of plugged blank section.	28.3
Elev./depth bottom of sand column.	28.4
Type of backfill below observation pipe. Grout	
Elev./depth of hole.	46

Well 36197

FIGURE 2 - WELL CONSTRUCTION FORM

GROUND WATER OBSERVATION WELL REPORT

PROJECT: RMA COE 89MC114A

LOCATION: SEC 36

Date Completed: 6-29-90 Original Depth: 30.2

Inspected By: TAT Date: 6-29-90

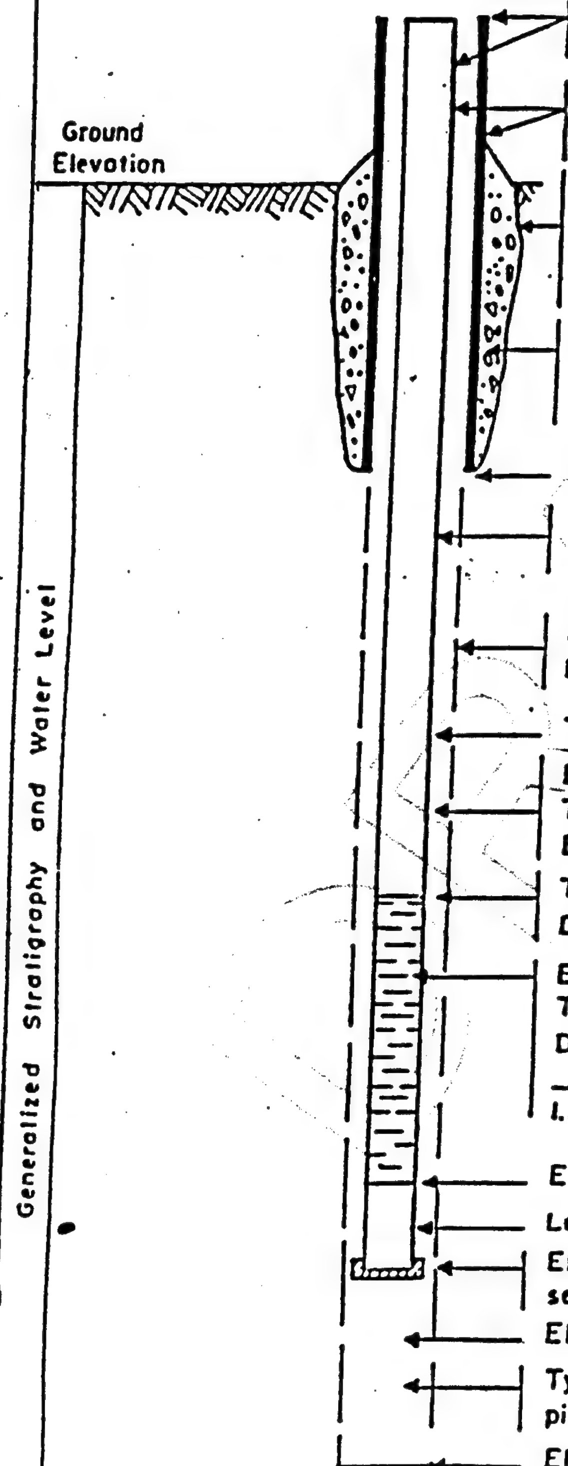
Checked By: ______ Date: ______

Page 1 of 1

Well No. LSB-35

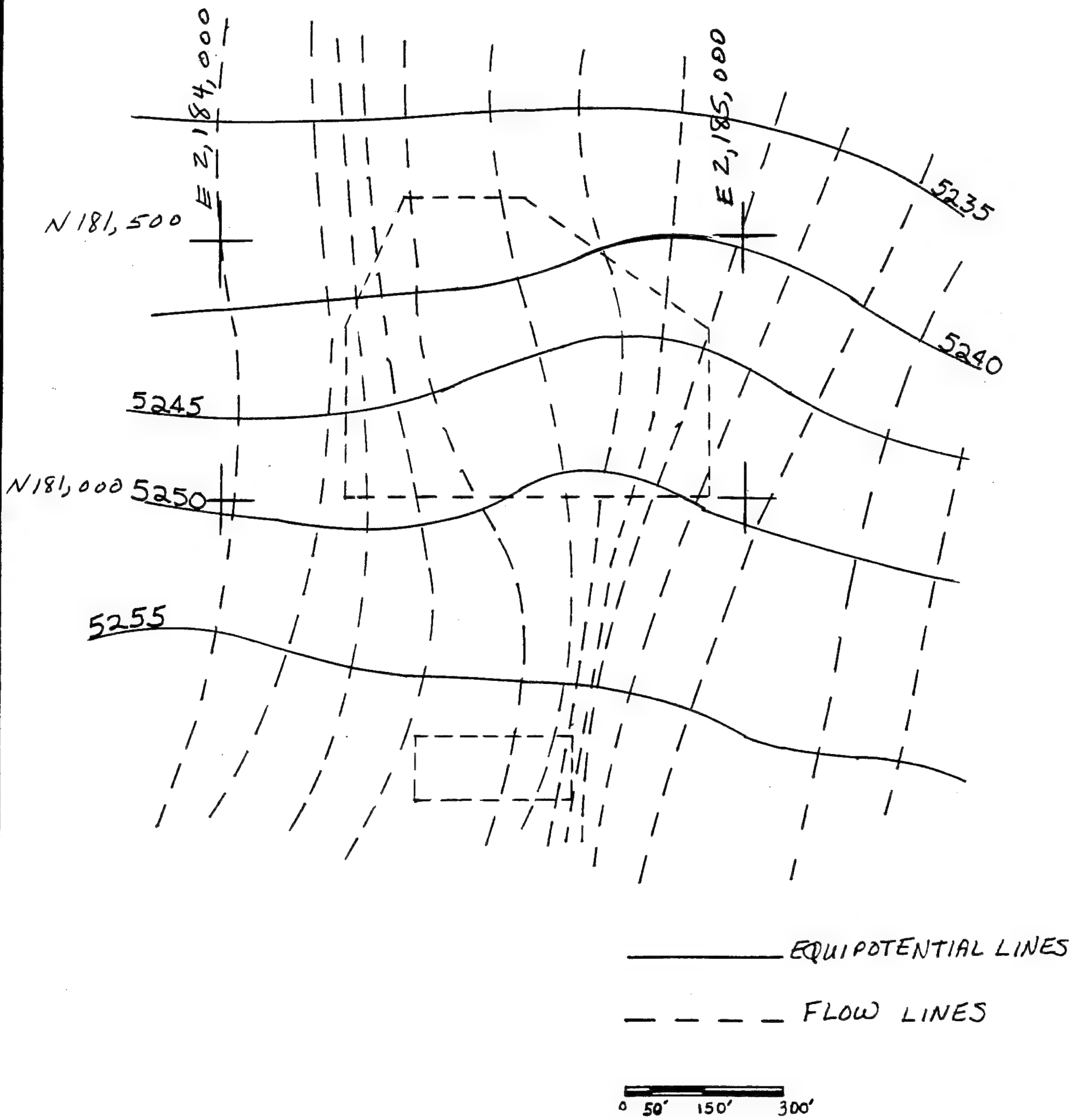
Aquifer: Alluvial

Depth Interval: ______



Elevation of top of surface casing / riser pipe.	*
Height of top of surface casing / riser pipe above ground surface	1.7
Depth of surface seal below ground surface	NA
Type of surface seal: NA	
I.D. of surface casing.	NA
Type of surface casing: NA	
Depth of surface casing below ground	NA
I.D. of riser pipe.	4in
Type of riser pipe: PVC	
Diameter of borehole	10
Depth of borehole	43.5 ~~[illegible]~~
Type of backfill: bentonite slurry	
Elev./depth top of seal.	10
Type of seal: betonite	
Elev./depth bottom of seal.	14
Type of sand pack. ______	
Depth of top of sand pack.	14
Elev./depth top of screened section.	19.9
Type of screened section: PVC	
Describe openings 10 slot	
I.D. of screened section.	4in
Elev./depth bottom of screened section.	29.9
Length of blank section.	0.3
Elev./depth bottom of plugged blank section.	30.2
Elev./depth bottom of sand column.	31
Type of backfill below observation pipe. grout	
Elev./depth of hole.	43.5

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA-LIME SETTLING BASINS	SHEET NO. 1 OF 1	
ITEM Flow DIAGRAM PRIOR TO ISOLATION CELL	BY JMC	DATE 8-10-90
	CHKD. BY	DATE



MRO Form 1550, 1 DEC 83

Bolton/gc/4169

CEMRO-ED-GF 23 August 1990

MEMORANDUM FOR Director, Missouri River Division Laboratory

SUBJECT: Request for Laboratory Services - Serial No. M-1045(Mil), Lime Settling Basins Slurry Wall, Rocky Mountain Arsenal, Denver, Colorado

1. The purpose of this request for services is to determine the permeability of a proposed slurry wall at the Lime Settling Basins Site when exposed to contaminants in the groundwater at the site.

2. Funds were sent to the MRD Laboratory on MIPR number ENE 0544, dated 25 April 1990. The cost code to be used is RJ0027052780099.

3. It is requested that the tests designated on the enclosed Laboratory Test Request be performed and that one copy of the testing report be sent to this office Attention: (CEMRO-ED-GF). In addition, a copy of all soil classification results should be sent to CEMRO-ED-GC.

FOR THE COMMANDER:

Encl

JOHN W. MONZINGO, P.E.
Chief, Geotechnical Branch
Engineering Division

MOSES/CEMRO-ED-GF

MONZINGO/CEMRO-ED-G

CF (wo/encl):
CEMRO-ED-MA

TEST REQUEST
ROCKY MOUNTAIN ARSENAL
TREATABILITY STUDY

1. Introduction. The following is an outline of the test procedures to be used for the Rocky Mountain Arsenal Lime Settling Basins Compatibility Study. Borrow material, slurry mix water, contaminated leachate, soil from the slurry wall borings and bentonite are already at the Lab. A schematic of the compatibility testing program is attached.

1.1. Geotechnical Test Methods. Where applicable, geotechnical testing shall be conducted in accordance with the Army Corps of Engineers Manual EM 1110-2-1906.

2. Determination of Bentonite Source. Potential bentonite sources must be premium-grade, ultrafine, natural sodium cation-based montmorillonite powders (Wyoming-type bentonite) that conforms to standards set forth in API Specification 13A, Sections 4, 8, and 9. Chemically treated bentonite will not be allowed. The bentonite samples at the Lab shall be tested for free swell using groundwater samples selected by the District. In addition, as a control, one free swell test shall be run on each bentonite sample using the anticipated slurry mix water. The free swell test method is described in EPA Report Number PB 87-229688 (EPA, 1987). The bentonite source which exhibits the least amount of variation between the control and contaminated groundwater free swell test will be used as the bentonite source for the backfill mixtures.

2.1. Bentonite Slurry Preparation. The bentonite slurry shall be prepared by mixing the slurry mix water with the previously selected bentonite source. The slurry shall be mixed with enough water to pass through a Marsh funnel in 40 to 50 seconds. The slurry shall be tested for density, moisture content, pH, and viscosity.

3. Borrow Sources. The borrow samples shall be stored in separate containers. All potential borrow material shall be tested for natural moisture content, Atterberg limits, grain size analysis (sieve and hydrometer methods), and specific gravity. No deleterious material will be allowed in any borrow material.

3.1 Chemical Analysis. The borrow material must be tested to verify it is free of contamination as determined by TCLP, TOC (Total Organic Carbon), sodium, calcium, magnesium, potassium, pH, and cation exchange capacity.

3.2. Preparation of Borrow Materials. The selected borrow will be oven-dried at 65 degrees Celsius for 2 to 4 days. The clays shall then be broken up, thoroughly mixed, and passed through a U.S. Standard Sieve No. 4. A sufficient quantity of oven dried material shall be retained for the optimization testing. The anticipated slurry mix tap water shall be added to the remainder of the dried and mixed materials until the original field water content is reached. The reconditioned borrow shall then be stored for 3 to 6 days in sealed containers at room temperature. During this storage period the samples should be mixed daily.

4. <u>In Situ Slurry Wall Soil</u>. Samples from the following Lime Settling Basins borings shall be thoroughly mixed to form one large sample: 11, 24, 9, 10, 26, and 18. This large sample shall be divided into two composite samples. Grain size analysis (sieve and hydrometer methods), Atterberg limits, and moisture content shall be run on each composite sample. Due to the consistency of the boring logs and field sieve analyses of the area, results of these two composite samples are expected to be very similar. One composite sample shall be used for optimization testing. Both samples will be used during permeameter testing (see paragraph 6).

5. <u>Optimization Testing</u>. Optimization tests will be performed to determine the most economical combination of materials for the backfill mixture. The percentage of fines, bentonite, coarse grained material, and water will be varied to produce the most economical backfill mixture which meets the 1×10^{-7} cm/sec permeability criteria.

The optimization test procedure shall consist of the following steps:
- Add sufficient oven dried (65 degrees Centigrade) borrow material to the selected oven dried composite sample so that the sample contains 20 % fines.
- Add sufficient oven dried borrow material to produce 4 additional samples which contain 30, 40, 50, and 60 % fines respectively.
- Place each sample in a constant volume mold and determine the respective dry densities. Plot percent fines vs. dry density.
- Slurry mix water shall be added to each composite sample until the anticipated field water content is reached.
- Run fixed wall permeability tests on each of these samples. The permeability tests shall be run at a differential head of 2 psi. Each permeability specimen shall be sluiced with tap water to obtain a 3 to 6 inch slump prior to being placed in the fixed wall permeameter. The length of test should be 8 to 24 hours.
- Based on the permeability test results, the District shall select a single mix which will most economically provide a permeability of 1×10^{-7} cm/sec or less after the addition of bentonite.
- The selected mix shall then be split into 3 samples. Two, 4, and 6 percent bentonite by dry weight shall be added to each of the 3 moist samples respectively. Each sample shall be sluiced with bentonite slurry to obtain a 3 to 6 inch slump. Each sample shall then be split into 2 specimens and fixed wall permeability tests run on each using the same test procedures outlined previously in this section. The length of test should be 24 to 48 hours. From this data, a plot of permeability vs. total percent bentonite will be made.
- A mixture which most economically meets or exceeds the permeability requirements will then be selected by the District for further evaluation as the backfill mixture.

5.1. <u>Borrow Soil Optimization Testing</u>. Optimization tests shall also be performed on the borrow material only. In this situation only the amounts of bentonite and water shall be varied. The last two steps of the above procedure shall also be carried out on the borrow material.

6. <u>Preparation of Backfill Mixture For Compatibility Testing</u>. One composite sample shall be permeameter tested at two percent higher bentonite content than selected during the optimization testing phase. The other composite sample will be permeameter tested at twice that percent bentonite. Two sets of compatibility tests (optimum+2% and twice [optimum+2%] bentonite)

also will be performed with the borrow soil only. Enough bentonite slurry shall be added to the reconditioned backfill mixture to achieve a slump in the range of 3 to 6 inches according to ASTM Test Method C 143-71 for determining concrete slump. The backfill mixture shall be stored in sealed containers at room temperature until loading into the permeameters for permeability testing.

7. Testing of Backfill Mixture. Atterberg limits, grain size analysis (mechanical analysis and hydrometer), moisture content, and specific gravity shall be run on the selected backfill mixture. A chemical analyses shall be performed on the selected backfill mixture as outlined in paragraph 3.1.

7.1. Initial Permeability Tests. One fixed wall permeability test shall be performed on each of the final backfill mixtures (borrow soil only and borrow soil plus in situ slurry wall soil) at optimum+2% bentonite using slurry mix water as the permeant to provide an initial estimate of the permeability. The length of this test shall be 24 to 48 hours.

8. Evaluate Permeant Effects. Three flexible wall permeameters shall be loaded with the selected backfill mixture, backpressure saturated, and leached with slurry mix water until one pore volume has passed through. Then two of the the backfill mixtures shall be leached with the contaminated groundwater samples until at least two pore volumes have passed through. The third specimen shall serve as a control test. It will be leached with only slurry mix water throughout the duration of the test. The time taken for each pore volume of fluid to move through the specimens shall be noted.

The following hydraulic gradients shall be applied to the specimens:

- 28 for the control sample which uses only slurry mix water as the permeant. Confining pressure = 5 psi.
- 28 for one of the samples using ground water as the permeant. Confining pressure = 5 psi.
- 56 for the other sample using groundwater as the permeant. Confining pressure = 5 psi.

The specimens shall be placed into the cells manually in order to reduce the amount of entrapped air. Porous stones (25 to 50 micron opening), with glass fiber filter paper (Whatman type 2), placed on the sample side of the stones will allow undisturbed flow of the permeant through the backfill samples. Effluent from the permeameters will be tested for chemical constituents after each pore water volume has passed through each specimen. The following chemical constituents will be tested for: TOC, specific conductivity, bromide, pH, alkalinity, sodium, calcium, chloride, VOA (Volatile Organics), and BNA (Base Neutral Acid Extractible Organics). The latter two methods should check for chemicals on the Priority Pollutant list. These same tests should also be performed on the groundwater prior to permeameter testing. This data will be used to estimate the amount of contaminant adsorption/desorption taking place.

9. Pre-test and Post-test Sample Examinations and Photo Documentation. Before the backfill mixture is loaded into the permeameters, comments on the general appearance, i.e. color and texture, of the material shall be recorded. The backfill mixture, before loading into the permeameters, shall be photographed. Photographs of the bentonite slurry shall also be taken.

As the permeameters are opened after completion of the tests, a visual examination of the samples shall be performed. The purpose of the visual examination is to determine whether months of testing has altered the general appearance of the sample. Similar comments to those mentioned above in the pre-test examination shall be recorded upon visual examination of the post-test backfill materials. Photographs of the backfill materials after testing shall be taken.

10. Reporting of Test Results. The results of the compatibility testing shall be presented to the Omaha District. The reported results should include the following:

-Evaluation of bentonite sources.
-Summary of bentonite slurry preparation.
-Chemical and physical test results of borrow sources.
-Summary of optimization testing performed and results of optimization testing.
-Summary of backfill preparation procedures and results from tests performed on backfill mixture.
-Results of all permeability tests performed on backfill mixtures including chemical analyses of the effluent. Permeabilities should be computed for each pore volume of fluid passing through each specimen.
-Test results of permeability tests performed on the aquitard soil.
-Pre-test and post-test sample examinations.

TREATABILITY STUDY FLOW CHART
ROCKY MOUNTAIN ARSENAL
IN SITU AND BORROW SOILS

GROUNDWATER
CHEMICAL TESTS
(PARA. 8)

BENTONITE
(PARA. 2)
FREE SWELL TESTS

CHOOSE 1

SLURRY PREPARATION
(PARA. 2.1)
CHARACTERIZATION TESTS

BORROW SOIL
SEE BOX ①, BORROW SOILS ONLY CHART

IN SITU SOILS
(PARA. 4)
COMBINE SOILS FROM FOLLOWING BORINGS: 11, 24, 9, 10, 26, 18
DIVIDE INTO 2 COMPOSITE SAMPLES
GRAIN SIZE, A.L., $w\%$ OF EACH COMPOSITE

OPTIMIZATION TESTING (1)
(PARA. 5)
OVEN DRY BORROW AND 1 COMPOSITE
MIX BORROW AND IN SITU SOIL TO PRODUCE SAMPLES WITH, 20, 30, 40, 50, AND 60% FINES
PLOT DRY DENSITY VS. % FINES
FIXED WALL PERMEABILITY TESTS 8-24 HRS, TAP WATER
SELECT ~~MIX~~ ECONOMICAL MIX

OPTIMIZATION TESTING (2)
(PARA. 5)
ADD BENTONITE SLURRY (2, 4, AND 6% BENTONITE, 3 TO 6 INCH SLUMP)
RUN 2 FIXED WALL PERMEAMETER TESTS FOR EACH % BENTONITE, 24 - 48 HRS.
PLOT k VS. % BENTONITE

SELECT LOWEST % BENTONITE WITH $k \leq 1 \times 10^{-7}$ cm/SEC

BACKFILL MIXTURE(S)
ONE COMPSITE: OPTIMUM + 2% BENTONITE
ONE COMPOSITE: TWICE [OPTIMUM + 2%] BENTONITE
CHEMICAL & CHARACTERIZATION TESTS (PARA 7)
INITIAL FIXED WALL PERMEABILITY TEST (PARA. 7.1)

CONT.

PERMEAMETER TESTS
(PARA. 8)

FOR BOTH MIXTURES:

CONTROL - MIX WATER ONLY, $i = 28$

GROUNDWATER PERMEANT, $i = 28$

GROUNDWATER PERMEANT, $i = 56$

CHEMICAL TESTS ON EFFLUENTS

REPORT (PARA. 10)

TREATABILITY STUDY FLOW CHART
ROCKY MOUNTAIN ARSENAL
BORROW SOIL ONLY

(1)
CHARACTERIZATION TESTS (PARA. 3)
CHEMICAL TESTING (PARA 3.1)
SAMPLE PREPARATION (PARA. 3.2)

↓

(2)
OPTIMIZATION TESTING
(PARA. 5.1)

24-48 HR. PERMEABILITY TESTS
2, 4, AND 6 PERCENT BENTONITE

↓

LOWEST % BENTONITE WITH
$k \leq 1 \times 10^{-7}$ cm/sec

↓

(3)
BACKFILL MIXTURE TESTING
CHEMICAL AND CHARACTERIZATION
(PARA 7.) OPTIMUM +2% BENTONITE
TWICE OPTIMUM +2% BENTONITE
INITIAL PERMEABILITY TEST
24-48 HR. OPTIMUM +2% BENTONITE
(PARA. 7.1)

↓

(4)
PERMEAMETER TESTING
(PARA. 8)

OPTIMUM +2% BENTONITE	TWICE OPTIMUM +2% BENTONITE
CONTROL - MIX WATER ONLY $i = 28$	CONTROL - MIX WATER ONLY $i = 28$
GROUNDWATER PERMEANT $i = 28$	GROUNDWATER PERMEANT $i = 28$
GROUNDWATER PERMEANT $i = 56$	GROUNDWATER PERMEANT $i = 56$

↓

REPORT (PARA. 10)

RMA LIME SETTLING BASINS COMPATIBILITY STUDY
(PROPOSED REVISION)

1. Compare bentonites using free swell test and filter cake compatibilitity test (Use fixed wall permeameters for filter cake test.)

2. Thoroughly composite samples from LSB0009, LSB 0024, LSB 0026, LSB 0023, LSB 0010, LSB 0017, LSB0022, LSB 0025).

3. Skip the "Dry Density vs % Fines" step using the constant volume molds due to poor correlations.

4. Skip the fixed wall permeability tests using non-bentonite mixes

5. Make up 3 samples (2 specimens each) using the composite insitu material (From Step 2) and 0, 2, and 4% dry bentonite. Adjust composite moisture content to simulate field moisture prior to adding the dry bentonite. MRO geotech will provide the MRD Lab with the required field moisture content value.

6. Add 40 second marsh funnel viscosity bentonite slurry to each of the 3 soil bentonite mixes (from step 5) to obtain an approximate 5" slump.

7. Run fixed wall permeability tests on the 3 soil-bentonite mixes (6 tests total).

8. Plot "Total % Bentonite vs. Permeability." If the permeability values meet MRO design requirements, proceed with step 13. If not, go to step 9.

9. Repeat steps 2 thru 7 using the composite insitu material plus the selected borrow material to obtain a new composite with approximately <u>10%</u> more fines than the original insitu composite. Adjust moisture contents of insitu and borrow material to simulate field moistures prior to adding dry bentonite. MRO geotech will provide input into which borrow matl. will be used along with the appropriate field moisture contents.

0. Plot "Total % Bentonite vs Permeability." If the permeability values meet MRO design requirements, proceed with step 13. If not, go to step 11.

1. Repeat steps 2 thru 7 using the composite insitu material plus borrow material to obtain a new composite with approximately <u>20%</u> more fines than the original insitu composite.

2. Plot "Total % Bentonite vs Permeability." If the permeability values meet MRO design requirements, proceed with step 13. If not, repeat steps 2 thru 7 using a new composite with approximately <u>30%</u> more fines than the original insitu composite.

. Run 3 triaxial long term permeabilities on the selected mix:

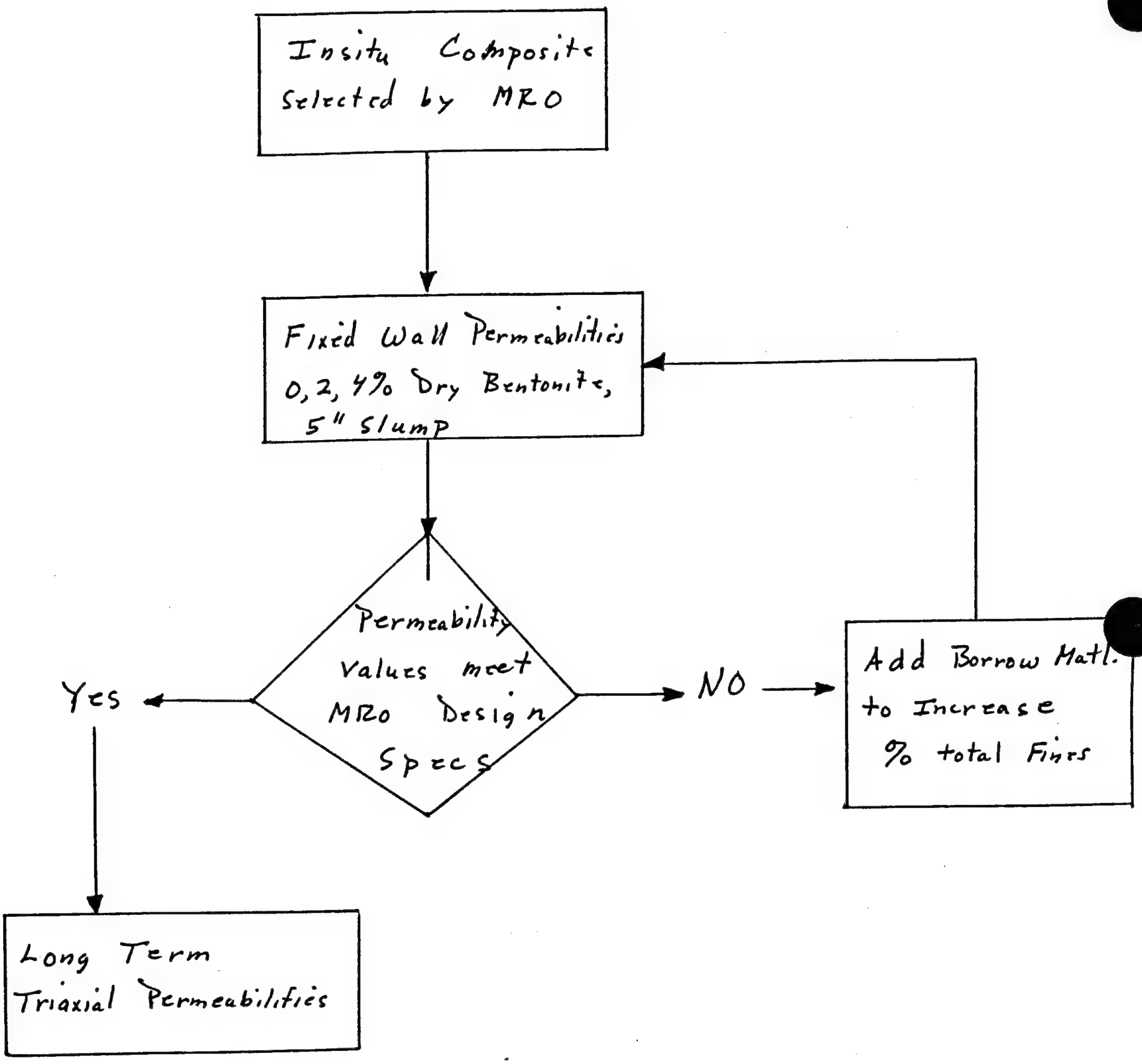
. Control test (Site water only) - Use selected mix w/% bentonite resulting in a permeability near the upper limit of the design permeability. (e.g. 1×10^{-7} cm/sec @ 2% bentonite)

) Run the second permeability test using the same mix as the control test but with leachate.

c) Run the third test using the selected mix w/% bentonite resulting in a permeability near the lower end of the permeability range for that mix. (e.g. 1×10^{-8} cm/sec @ 4% bentonite). Run the test with leachate.

The intent of the above revisions is to provide a more logical and hopefully more economical approach to selecting permeability mixes which better simulate actual slurry wall construction mixes. It assumes we start with a worst case insitu material and add up to 4% dry bentonite. Obviously, this should provide the most economical mix if design permeability requirements are met. The 4% cutoff is an arbitrary upper limit whereby we assume it would be more economical to add borrow fines rather than additional dry bentonite above this limit. If you agree with this revision, please submit a new test request with these changes to the MRD Lab as soon as possible.

Dave Jones


Insitu Composite Selected by MRO
Fixed Wall Permeabilities 0, 2, 4% Dry Bentonite, 5" Slump
Permeability Values meet MRo Design Specs
Yes
NO
Add Borrow Matl. to Increase % total Fines
Long Term Triaxial Permeabilities

UPDATED TEST REQUEST
ROCKY MOUNTAIN ARSENAL
TREATABILITY STUDY

OCTOBER 10, 1990

1. Introduction. The following is an outline of the test procedures to be used for the Rocky Mountain Arsenal Lime Settling Basins Compatibility Study. Borrow material, slurry mix water, contaminated leachate, soil from the slurry wall borings and bentonite are already at the Lab. A schematic of the compatibility testing program is attached.

1.1. Geotechnical Test Methods. Where applicable, geotechnical testing shall be conducted in accordance with the Army Corps of Engineers Manual EM 1110-2-1906.

2. Determination of Bentonite Source. Potential bentonite sources must be premium-grade, ultrafine, natural sodium cation-based montmorillonite powders (Wyoming-type bentonite) that conforms to standards set forth in API Specification 13A, Sections 4, 8, and 9. Chemically treated bentonite will not be allowed. The bentonite samples at the Lab shall be tested for free swell and filter cake compatibility testing using groundwater samples selected by the District. In addition, as a control, one free swell test shall be run on each bentonite sample using the anticipated slurry mix water. The free swell test method is described in EPA Report Number PB 87-229688 (EPA, 1987). A bentonite source will be chosen for further testing based on free swell and filter cake compatibility results.

2.1. Bentonite Slurry Preparation. The bentonite slurry shall be prepared by mixing the slurry mix water with the previously selected bentonite source. The slurry shall be mixed with enough water to pass through a Marsh funnel in 40 to 50 seconds. The slurry shall be tested for density, moisture content, pH, and viscosity.

3. Borrow Sources. The borrow samples shall be stored in separate containers. All potential borrow material shall be tested for natural moisture content, Atterberg limits, grain size analysis (sieve and hydrometer methods), and specific gravity. No deleterious material will be allowed in any borrow material.

3.1 Chemical Analysis. The borrow material must be tested to verify it is free of contamination as determined by TCLP, TOC (Total Organic Carbon), sodium, calcium, magnesium, potassium, pH, and cation exchange capacity.

3.2. Preparation of Borrow Materials. Enough borrow (clay and random fill) for optimization testing will be oven-dried at 65 degrees Celsius for 2 to 4 days. The clays shall then be broken up, thoroughly mixed, and passed through a U.S. Standard Sieve No. 4. The anticipated slurry mix tap water shall be added to the dried and mixed materials until the original field water content is reached. The reconditioned borrow shall then be stored for 3 to 6 days in sealed containers at room temperature. During this storage period the samples should be mixed daily.

4. <u>In Situ Slurry Wall Soil</u>. Samples from the following Lime Settling Basins borings shall be thoroughly mixed to form one composite sample: 11, 24, 9, 10, 26, and 18. Grain size analysis (sieve and hydrometer methods), Atterberg limits, and moisture content shall be run on this composite sample.

5. <u>Optimization Testing</u>. Optimization tests will be performed to determine the most economical combination of materials for the backfill mixture. The percentage of fines, bentonite, coarse grained material, and water will be varied to produce the most economical backfill mixture which meets the 1×10^{-7} cm/sec permeability criteria.

The optimization test procedure shall consist of the following steps:

a. Prepare 3 samples (2 specimens each) using the composite insitu material. If additional water is necessary to simulate field moisture content, RMA tap water will be added at this time. Dry bentonite will be added to the samples to obtain 0, 2, and 4% bentonite by weight.

b. Add bentonite slurry with a viscosity of 40 seconds (Marsh funnel) to each sample (from step a) to obtain an approximate 5 inch slump.

c. Run fixed wall permeability tests on the 3 soil-bentonite mixtures (6 tests total). Test length will be 24 to 48 hours.

d. Plot "Total Percent Bentonite vs. Permeability". If the permeability values are not less than or equal to 1×10^{-7} cm/sec, proceed with step e. Otherwise go on to paragraph 5.1.

e. Repeat steps a through c using the composite insitu material plus the clay borrow material to obtain a new composite with approximately 10% more fines than the original insitu composite. Adjust moisture contents as necessary to simulate field moisture conditions.

f. Plot "Total Percent Bentonite vs. Permeability". If permeability values are not less than or equal to 1×10^{-7} cm/sec proceed with step g. Otherwise go on to paragraph 5.1.

g. Repeat steps a through c using the composite insitu material plus the clay borrow material to obtain a new composite with approximately 20% more fines than the original insitu composite. Adjust moisture contents as necessary to simulate field moisture conditions.

h. Plot "Total Percent Bentonite vs. Permeability". If permeability values are not less than or equal to 1×10^{-7} cm/sec proceed with step i. Otherwise go on to paragraph 5.1.

i. Repeat steps a through c using the composite insitu material plus the clay borrow material to obtain a new composite with approximately 30% more fines than the original insitu composite. Adjust moisture contents as necessary to simulate field moisture conditions.

j. Plot "Total Percent Bentonite vs. Permeability". If permeability values are not less than or equal to 1×10^{-7} cm/sec notify MRO-GF.

5.1. <u>Borrow Soil Optimization Testing</u>. Optimization tests shall also be performed using the random fill borrow material in place of the insitu soil.

5.2. If none of the insitu soil-fines-bentonite mixtures results in a permeability on the order of magnitude of 10^{-7} cm/sec while mixture(s) of random fill borrow-fines-bentonite do, then long-term permeability tests will be performed using only random fill borrow as the principal soil constituent. If the desired permeability is obtained by mixtures including insitu soil and

random fill borrow, long-term permeability tests will be performed using both principal soil constituents.

6. Preparation of Backfill Mixture For Compatibility Testing. Soils to be used for long-term permeability tests shall be prepared as specified in paragraph 3.2, Preparation of Borrow Materials. Prepared backfill mixtures shall be stored in sealed containers at room temperature until loading into the permeameters for permeability testing.

7. Testing of Backfill Mixture. Atterberg limits, grain size analysis (mechanical analysis and hydrometer), moisture content, and specific gravity shall be run on the selected backfill mixtures.

8. Evaluate Permeant Effects. Three flexible wall permeameters shall be loaded with the backfill mixture, backpressure saturated, and leached with slurry mix water until one pore volume has passed through. Then two of the the backfill mixtures shall be leached with the contaminated groundwater samples until at least two pore volumes have passed through. The third specimen shall serve as a control test. It will be leached with only slurry mix water throughout the duration of the test. The time taken for each pore volume of fluid to move through the specimens shall be noted. The hydraulic gradient will be 28 with a confining pressure of 5 psi. The mixtures shall be as follows:

a. Control (tap water only) - the selected mix with the percent bentonite which produced a permeability near 1×10^{-7} cm/sec during optimization testing.

b. Same mix and percent bentonite as control with contaminated groundwater as permeant after the first pore volume.

c. Same mix as control with a higher bentonite content that produces a permeability close to 1×10^{-8} cm/sec, with contaminated groundwater as permeant after the first pore volume.

The specimens shall be placed into the cells manually in order to reduce the amount of entrapped air. Porous stones (25 to 50 micron opening), with glass fiber filter paper (Whatman type 2), placed on the sample side of the stones will allow undisturbed flow of the permeant through the backfill samples. Effluent from the permeameters will be tested for chemical constituents after each pore water volume has passed through each specimen. The following chemical constituents will be tested for: TOC, specific conductivity, bromide, pH, alkalinity, sodium, calcium, chloride, VOA (Volatile Organics), and BNA (Base Neutral Acid Extractible Organics). The latter two methods should check for chemicals on the Priority Pollutant list. These same tests should also be performed on the groundwater prior to permeameter testing. This data will be used to estimate the amount of contaminant adsorption/desorption taking place.

9. Pre-test and Post-test Sample Examinations and Photo Documentation. Before the backfill mixtures are loaded into the permeameters, comments on the general appearance, i.e. color and texture, of the material shall be recorded. The backfill mixture, before loading into the permeameters, shall be photographed. Photographs of the bentonite slurry shall also be taken.

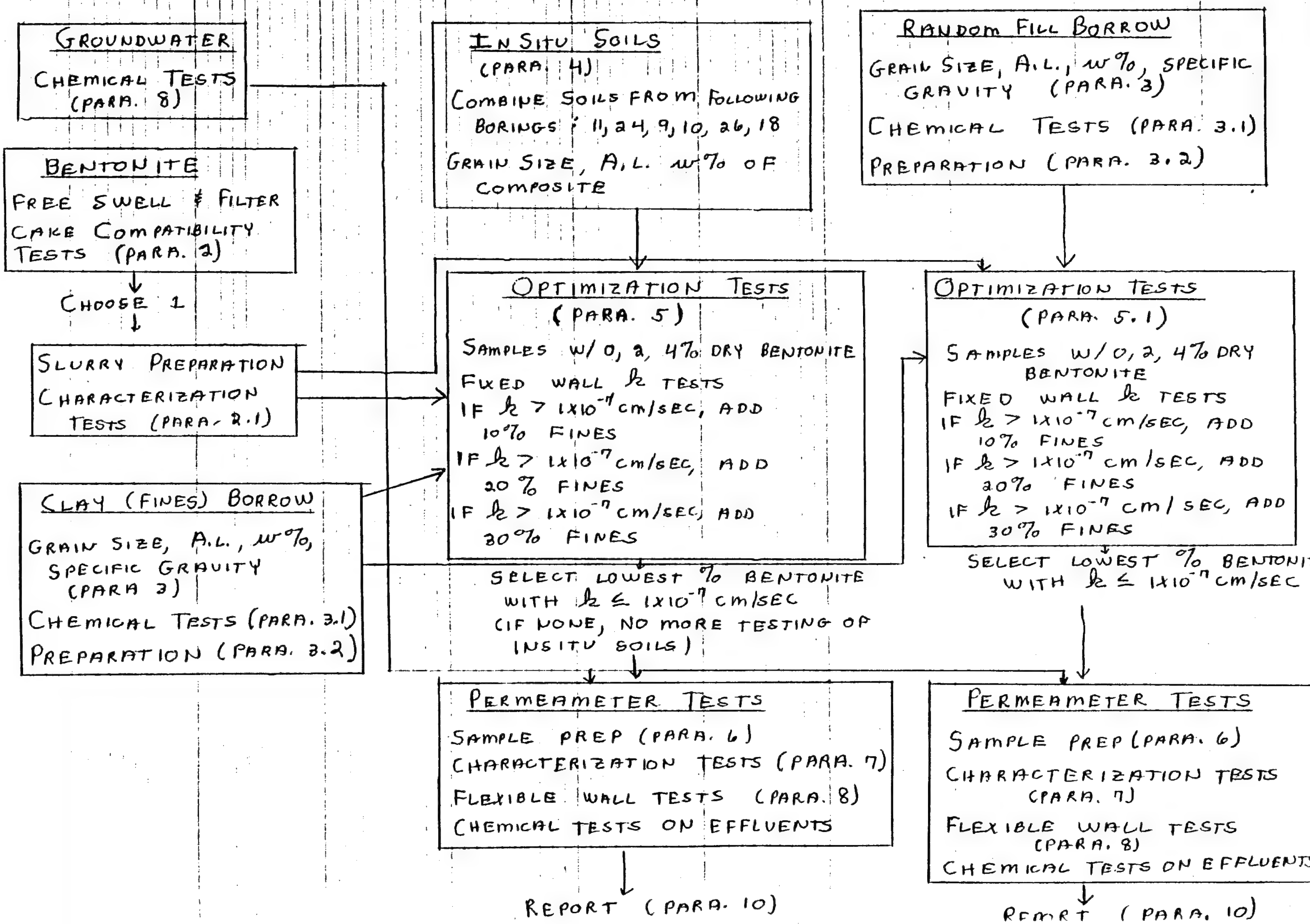
As the permeameters are opened after completion of the tests, a visual examination of the samples shall be performed. The purpose of the

visual examination is to determine whether months of testing has altered the general appearance of the sample. Similar comments to those mentioned above in the pre-test examination shall be recorded upon visual examination of the post-test backfill materials. Photographs of the backfill materials after testing shall be taken.

10. Reporting of Test Results. The results of the compatibility testing shall be presented to the Omaha District. The reported results should include the following:

-Evaluation of bentonite sources.
-Summary of bentonite slurry preparation.
-Chemical and physical test results of borrow sources.
-Summary of optimization testing performed and results of optimization testing.
-Summary of backfill preparation procedures and results from tests performed on backfill mixture.
-Results of all permeability tests performed on backfill mixtures including chemical analyses of the effluent. Permeabilities should be computed for each pore volume of fluid passing through each specimen.
-Pre-test and post-test sample examinations.

ROCKY M TAIN ARSENAL
UPDATED TREATABILITY STUDY FLOW CHART



EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
15 Loveton Circle
Sparks, MD 21152
(301) 771-4950
Atlanta • Baltimore • Chicago • Dallas • Lincoln
Angeles • New Jersey • New York • San Francisco

LETTER OF TRANSMITTAL

DATE	JOB NO.
24 August 1990	10424.03

ATTENTION Mr. Dave Jaros

RE: Kane & Lombard Superfund

TO USACE
MRD Laboratories
420 South 18th Street
Omaha, NE 68102-2586

WE ARE SENDING YOU ☐ Attached ☐ Under separate cover via ______ the following items:

☐ Shop drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications

☐ Copy of letter ☐ Change order ☐ ______

COPIES	DATE	NO.	DESCRIPTION
1			Memo from Geo Con

THESE ARE TRANSMITTED as checked below:

☐ For approval ☐ Approved as submitted ☐ Resubmit ____ copies for approval

☐ For your use ☐ Approved as noted ☐ Submit ____ copies for distribution

☐ As requested ☐ Returned for corrections ☐ Return ____ corrected prints

☐ For review and comment ☐ ______

☐ FOR BIDS DUE ______ 19 ____ ☐ PRINTS RETURNED AFTER LOAN TO US

REMARKS Dave,

I received a copy of this memo from Geo Con concerning bentonite specified for use at K&L. This may be of interest to you in considering revisions to USACE guide specs for hazardous waste slurry wall construction.

COPY TO File

SIGNED Gregory E. Johnson
Gregory E. Johnson, P.E., CHMM
Project Manager

EA 0110 4/11/88

If enclosures are not as noted, kindly notify us at once.

AE-1

GEO•CON® INC.
GEOTECHNICAL CONTRACTING

S9-H029 Letter No. 045

August 8, 1990

RECEIVED
16 AUG 1990
NSA Area Office
NACF-RA

Department of the Army
Baltimore District, Corps of Engineers
P. O. Box 242
Fort George G. Meade, MD 20755-0242

Attn: Mr. Bob Craig

Bentonite Clay
API 13A Section 5
Slurry Wall
Kane and Lombard Superfund Site
Contract DACW45-89-C-0507
Baltimore, Maryland

Dear Mr. Craig:

As you know a new bentonite product was specified for use in the slurry wall on the above referenced project. This new product is tentatively specified by the American Petroleum Institute (API) under Specification 13A, Section 5: Nontreated Bentonite (Tentative). The usual product is premium grade, 90 bbl/ton yield, API 13A Section 4 bentonite clay. This letter presents our evaluation of this product based on our experience at the Kane and Lombard project.

At the Kane and Lombard project we mixed the bentonite slurry to a 40 MFV in our 5 cy colloidal mixer. This mixer fully hydrates the slurry during the retention time of the plant. Our excavations encountered two different areas; 1) a 15 ft. deep excavation through primarily clay, and 2) a 30 ft. deep excavation through primarily refuse. Typically, we would expect a usage factor of 4-5 pounds of bentonite per square foot in the clay excavation and 10-15 pounds per square foot in the refuse. On this project our usage was 10-12 pounds per square foot in both areas. In addition, in the refuse our filtrate loss in the trench occasionally exceeded 40 cc, however, our trench was stable and we had no cave-ins. All permeability tests were acceptable and a high quality slurry wall is now in place.

We find two areas of concern with the performance of this new bentonite product. First, in the area of normal slurry trenching, the usage was excessive and unexpected. Second, in the refuse area the usage did not respond adequately to the refuse conditions; i.e. our filtrate was excessive and a cave-in was only avoided by our extra efforts. Considering the premium price of this new product, the results described above were very disappointing.

A review of the Section 5 specification may provide some of the answers. This clay is treated with a deflocculant (sodium hexametaphosphate) prior to testing the yield. This technique results in erroneous and misleading results and is totally different from any other API test. In our opinion, the Section 5 product performed like a sub-API 13A product normally used in the foundry industry (yield = 50-80 bbl/ton).

P.O. Box 17380 • Pittsburgh, PA 15235 • Tel (412)856-7700 • FAX (412)373-3357

Texas Office (817)383-1400
California Office (408)453-3587
Florida Office (813)647-5888
New Jersey Office (609)848-2220

GEO·CON® INC.

We would not recommend this product for slurry trenching. If the aim of this new specification is a better product, the specification has failed. If bentonite/leachate compatibility is a concern, it is recommended engineering practice to test the compatibility of various bentonite products prior to specifying the bentonite. Therefore, an adequate testing program will determine what type of bentonite is acceptable. Our solution to buying quality bentonite has been to rely on a limited number of vendors with a proven product and perform regular testing of our own. Our suppliers of API 13A, Section 4 bentonite have a high quality base clay and add only about 0.5 pounds of polymer additive per ton of bentonite (0.025%). This generally results in a much more predictable product. We do not recommend that so called "contaminate resistant" bentonites with proprietary treatments. As slurry specialists we cannot recommend bentonite with excessive polymer treatment, however, bentonite is, after all, only soil and some limited treatment can be beneficial. In the end it takes qualified slurry specialists in the field and knowledgeable engineers to produce quality installations.

This letter is provided to you for informational purposes only, no response is necessary. We do, however, wish to register our dissatisfaction with this new product and specification so that the Corps of Engineers and API can take appropriate measures in the future.

Sincerely,

GEO-CON, INC.

Steven R. Day
Slurry Wall
Group Manager

David A. Sandstrom
Liner Division
Group Manager

SRD/DAS/lmw

cc: American Petroleum Institute
Production Department
2531 One Muir Place
Dallas, TX 75202-3904
Attn: Mike Laudermilk

J. Kohli

Kaned Lombard

ZERO ACCIDENTS

SECTION 02214

SOIL-BENTONITE SLURRY CUTOFF WALL

INDEX

1. SCOPE. The work covered by this section of the Specifications consists of furnishing all parts, labor, equipment, and materials and of performing all operations in connection with constructing the soil-bentonite slurry cutoff wall, hereinafter referred to as the slurry trench, in accordance with these specifications and contract drawings.

2. APPLICABLE PUBLICATIONS. The following publications of the issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the reference thereto.

2.1. AMERICAN PETROLEUM INSTITUTE (API) STANDARD SPECIFICATIONS.

Code RP13B 12th Ed. Sept 1988	Recommended Practice Standard Procedures for Testing Drilling Fluids; and Supplements
Spec. 13A Sections 3,5,6, 7, and 8 12th Ed. Sept 1988	Specification for Oil-Well Drilling Fluid Materials

2.2. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS.

D 1140-57	Materials Finer than 75 µm (No. 200) Sieve in Mineral Aggregates by Washing
C 136-83	Sieve Analysis of Fine and Coarse Aggregates
D 2217-66	Wet Preparation Method
C 143-78	Slump of Portland Cement Concrete
D 698-78	Test for Moisture-Density Relations of Soils and Soil-Aggregate Mixture, Using 5.5-pound Hammer and 12-inch Drop
D 422-63	Particle-Size Analysis of Soils
D 1586-67	Standard Penetration Test
D 1587-83	Thin Walled Tube Sampling of Soils
D 4318-84	Liquid Limit, Plastic Limit, and Plasticity Index of Soils

2.3. CORPS OF ENGINEERS MANUALS.

EM 1110-2-1906 Appendix VI (Dated 20 August with Change 2)	Laboratory Soils Testing
EM 1110-2-3506	Grouting Technology

7.6. DISPOSAL OF DRILL CUTTINGS. All drill cuttings will be handled and disposed in accordance with SECTION: HANDLING AND DISPOSAL OF CONTAMINATED MATERIALS.

8. NOT USED.

9. MATERIALS. The requirements for the materials to be utilized in the slurry trench construction are as follows.

9.1. BENTONITE. The bentonite shall be sodium cation base montmorillonite powder (Premium Grade Wyoming-type bentonite) that conforms to the standards set forth in API Specification 13A, Section 3, 5, 6, 7, and 8 as last revised. No chemically treated bentonite will be allowed. The Contractor shall furnish to the Contracting Officer a certificate of compliance and a copy of the test reports from the bentonite manufacturer for each lot of bentonite shipped to the site stating that the bentonite complies with all applicable standards. No bentonite from the bentonite manufacturer shall be used prior to acceptance by the Contracting Officer. All bentonite will be subject to inspection, sampling, and verification of quality of testing by or under the supervision of the Government. Bentonite not meeting specifications shall be promptly removed from the site of the work and replaced with bentonite conforming to specifications requirements at the Contractor's expense. Bentonite shall be protected from moisture during transit and storage.

9.2. WATER. The Contractor shall supply all water required for mixing with bentonite to produce slurry. The water shall be clean, fresh, and comply with the standards specified below.

a. A pH equal to 7.0±1.0.

b. Total dissolved solids not greater than 500 parts per million.

c. Oil, organics, acids, alkali, or other deleterious substances not greater than 50 ppm each.

d. Hardness less than or equal to 50 ppm.

e. Ground water from the site is specifically excluded from use.

The Contractor shall furnish water quality test results for water used for mixing the bentonite slurry to assure conformance with the above limits.

9.3. BENTONITE SLURRY. The bentonite slurry for supporting the sides of the trench and that mixed with the backfill shall consist of a stable colloidal suspension of powdered, premium-grade natural bentonite in water. It is the responsibility of the Contractor that the slurry meets the necessary properties. The properties of the slurry used in all construction sequences shall be in accordance with the testing procedures described in API Code RP13B and shall conform to the following requirements:

9.3.1. Initial Bentonite Slurry Mixture. At the time of introducing bentonite slurry into the trench excavation, the slurry mixture shall have a minimum apparent viscosity of 40 seconds as measured by the Marsh funnel. The slurry density shall be a minimum of 65 pounds per cubic foot. The water loss shall not be greater than 30 cubic centimeters in 30 minutes as measured by a filter press at 100 psi. The pH shall not be less than 8.0. Mixture adjustment shall conform to the requirements in subparagraph: Additional Bentonite.

9.3.2. Trench Bentonite Slurry Mixture. The minimum apparent viscosity of the bentonite slurry mixture in the trench at any time shall be 40 seconds as measured by the Marsh funnel and the maximum shall be low enough to flow through the Marsh funnel. The density of the slurry mixture at the time

MOISTURE DETERMINATIONS

Project	RMA
Location Samples	(SAVE SOIL)
Lab. Serial No.	Date Tested

Type of Test	COELSB 0025	25 BORE 007	25 BORE 006	COELSB 0010	COELSB 0022	COELSB 0023	COELSB 0026	COELSB 0024
Pan No.	P-67	P-65	P-64	P-63	P-62	P-66	P-69	P-50
Weight of Pan and Wet Soil	122.5	129.8	131.9	113.2	154.9	186.7	127.1	134.6
Weight of Pan and Dry Soil	106.6	119.4	123.1	99.9	138.3	159.5	111.8	124.0
Weight of Pan	53.0	53.3	53.8	53.0	53.0	53.0	52.4	53.0
Weight of Dry Soil								
Weight of Moisture								
Percent Moisture	29.7	15.7	12.7	28.4	19.5	25.5	25.8	14.9
Average Moisture								

Type of Test	COELSB 0017	COELSB 0009	25 BORE 008	25 BORE 009				
Pan No.	P-58	P-57	P-56	P-55				
Weight of Pan and Wet Soil	147.0	150.1	153.1	140.2				
Weight of Pan and Dry Soil	129.3	132.6	141.2	129.2				
Weight of Pan	52.5	53.7	53.8	53.2				
Weight of Dry Soil								
Weight of Moisture								
Percent Moisture	23.0	22.2	13.6	14.5				
Average Moisture								

Remarks:

Tested by: Date:

Computed by: Date:

Checked by: Date:

MRH Form 464 (29 Jul 46) Replaces Lab. Form No. 8

MOISTURE DETERMINATIONS

Project	RMA
Location Samples	Random Fill Samples 1 + 2
Lab. Serial No.	Date Tested

Type of Test	Sample 1 JAR		Bag					
Pan No.	7		8					
Weight of Pan and Wet Soil	188.0		247.6					
Weight of Pan and Dry Soil	165.8		237.1					
Weight of Pan	56.8		56.8					
Weight of Dry Soil								
Weight of Moisture								
Percent Moisture	20.4		5.8					
Average Moisture								

Type of Test	Sample 2 Jar		Bag					
Pan No.	9		10					
Weight of Pan and Wet Soil	180.0		230.1					
Weight of Pan and Dry Soil	164.2		213.6					
Weight of Pan	56.8		56.8					
Weight of Dry Soil								
Weight of Moisture								
Percent Moisture	14.7		10.5					
Average Moisture								

Remarks:

Tested by: Date:

Computed by: Date:

Checked by: Date:

MRH Form 464 (29 Jul 46) Replaces Lab. Form No. 8

3

M-43 78

LIQUID AND PLASTIC LIMIT TESTS

For use of this form, see EM 1110-2-1906.

(A)

DATE 9-20-90

PROJECT Rocky Mountain Arsenal

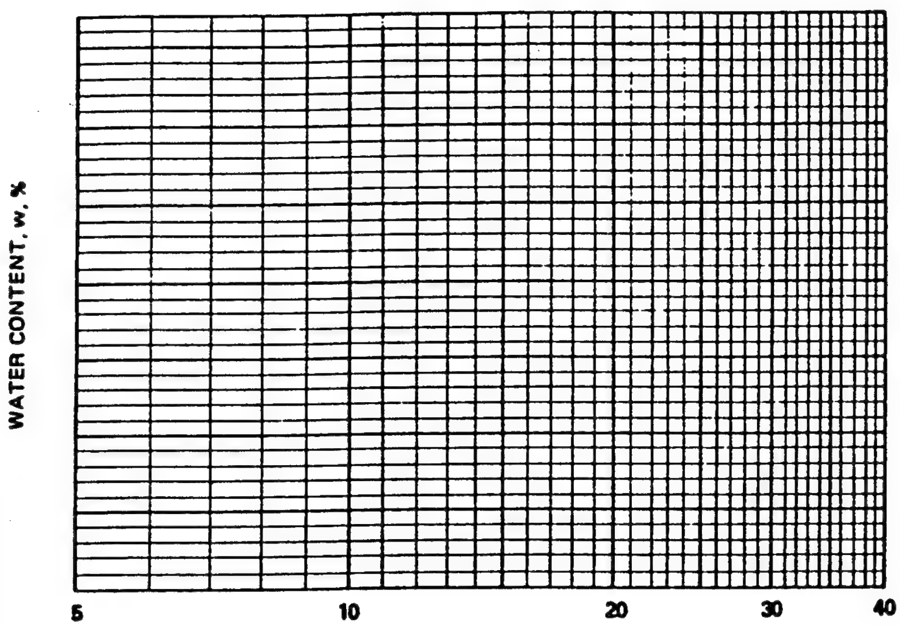
BORING NO. COE/SB 0025 SAMPLE NO. Composite

LIQUID LIMIT

		RUN NO.	1	2	3	4	5	6
		TARE NO.	5	6				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		7.718	5.641				
	TARE PLUS DRY SOIL		5.774	4.36				
	WATER	W_w						
	TARE		1.505	1.53				
	DRY SOIL	W_s						
WATER CONTENT, %		w	45.5	45.3				
NUMBER OF BLOWS			22	25				

44.8

(SAVE H_2O & SOIL)



LL 45.3

PL 27.4

PI 17.9

Symbol from plasticity chart ML

PLASTIC LIMIT

		RUN NO.	1	2	3	4	5	NATURAL WATER CONTENT
		TARE NO.	7	9				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		3.145	3.28				
	TARE PLUS DRY SOIL		2.792	2.914				
	WATER	W_w						
	TARE		1.522	1.531				
	DRY SOIL	W_s						
WATER CONTENT, %		w	27.8	27.0				
PLASTIC LIMIT								

REMARKS

TECHNICIAN ______ COMPUTED BY ______ CHECKED BY ______

ENG FORM 1 JUN 65 3838

PLATE III-1

~~1-A~~
221

GRAIN SIZE ANALYSIS

A

Date: 9-20-90

Project No.: ____________

Project: ROCKY MOUNTAIN ARSENAL

Location of Sample: COELSB 0025

Sample Description: MOTTLED LIGHT BROWN & GRAY

USCS: ____________ AASHTO: ____________

Liquid Limit: ______ Plastic Index: ______

Remarks: COMPOSITE 2.5', 5', 7.5', 10', 15', & 20'
(SAVE H_2O & SOIL)

☒ Mechanical analysis

☐ Hydrometer analysis

Data Sheet 1 - Mechanical

	Initial Sample	After Wash
Dry Sample and Tare=		
Tare=		
Dry Sample Weight=	105.8	
Calculated -200=		

Tare For Cumulative Weight Retained= ____________

MECHANICAL ANALYSIS

J.S. STANDARD SIEVE IZE(MM)	SIEVE NO.	SAMPLE WT.	% COARSER	% FINER
76.2	3 INCH	0.0	0.0	100.0
38.1	1 1/2 INCH	0.0	0.0	100.0
19.1	3/4 INCH	0.0	0.0	100.0
9.52	3/8 INCH	0.0	0.0	100.0
4.76	NO. 4	0.0	0.0	100.0
PAN		0.0	0.0	100.0
TOTAL		0.0		
ACTOR		0.9452		
.10	2.00	5.1	4.8	95.2
. 20	0.84	8.7	8.2	91.8
. 40	0.42	13.8	13.0	87.0
. 80	0.177	35.5	33.6	66.4
.200	0.074	69.7	65.9	34.1
PAN		105.8	100.0	0.0

ter:
ue: 105.8
kcheet: mech2 Loc: n98o5

FN: 0 Font: Standard

D-35 10 5 . B

LIQUID AND PLASTIC LIMIT TESTS

For use of this form, see EM 1110-2-1906.

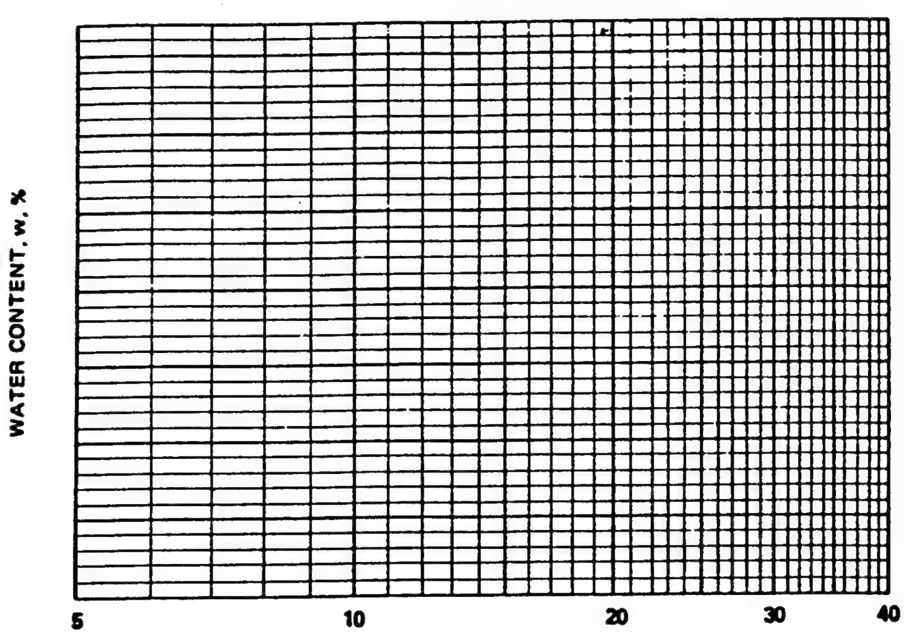
PROJECT Rocky Mountain Arsenal DATE 9-26-90

BORING NO. COELSBØØ23 SAMPLE NO. Composite

LIQUID LIMIT

			1	2	3	4	5	6
	RUN NO.		1	2	3	4	5	6
	TARE NO.		13	14				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		7.902	8.998				
	TARE PLUS DRY SOIL		6.301	7.133				
	WATER	W_w						
	TARE		1.505	1.533				
	DRY SOIL	W_s						
	WATER CONTENT, %	w	33.4	33.3				
	NUMBER OF BLOWS		23	25				

33.1



LL 33.0

PL 14.7

PI 18.3

Symbol from plasticity chart CL

Med tough

PLASTIC LIMIT

			1	2	3	4	5	NATURAL WATER CONTENT
	RUN NO.		1	2	3	4	5	
	TARE NO.		15	16				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		4.356	4.594				
	TARE PLUS DRY SOIL		3.993	4.199				
	WATER	W_w						
	TARE		1.506	1.525				
	DRY SOIL	W_s						
	WATER CONTENT, %	w	14.6	14.8				
	PLASTIC LIMIT							

REMARKS

TECHNICIAN COMPUTED BY CHECKED BY

ENG FORM 1 JUN 65 3838 PLATE III-1

E-67

GRAIN SIZE ANALYSIS

B

Date: 9-26-90

Project No.: ____________

Project: ROCKY MOUNTAIN ARSENAL B

Location of Sample: COELSB ØØ23 COMPOSITE

Sample Description: BROWN

USCS: ____________ AASHTO: ____________

Liquid Limit: ______ Plastic Index: ______

Remarks: ____________

☒ Mechanical analysis

☐ Hydrometer analysis

Data Sheet 1 - Mechanical

	Initial Sample	After Wash
Dry Sample and Tare=		
Tare=		
Dry Sample Weight=	113.0	

Calculated -200= ____________

Tare For Cumulative Weight Retained= ____________

Sieve	Weight	Tare	Cum.	%

MECHANICAL ANALYSIS

U.S. STANDARD SIEVE SIZE(MM)	SIEVE NO.	SAMPLE WT.	% COARSER	% FINER
76.2	3 INCH	0.0	0.0	100.0
38.1	1 1/2 INCH	0.0	0.0	100.0
19.1	3/4 INCH	0.0	0.0	100.0
9.52	3/8 INCH	0.0	0.0	100.0
4.76	NO. 4	0.0	0.0	100.0
PAN		0.0	0.0	
TOTAL		0.0		
ACTOR		0.8850		
IO.10	2.00	0.0	0.0	100.0
IO. 20	0.84	1.4	1.2	98.8
O. 40	0.42	11.0	9.7	90.3
O. 80	0.177	43.2	38.2	61.8
O.200	0.074	79.9	70.7	29.3
PAN		113.0	100.0	0.0

ater:
alue: 113
orksheet: mech2 Loc: r28c5

M-36 3/8

LIQUID AND PLASTIC LIMIT TESTS

For use of this form, see EM 1110-2-1906.

(C)

PROJECT Rocky Mountain Arsenal DATE 9-20-90

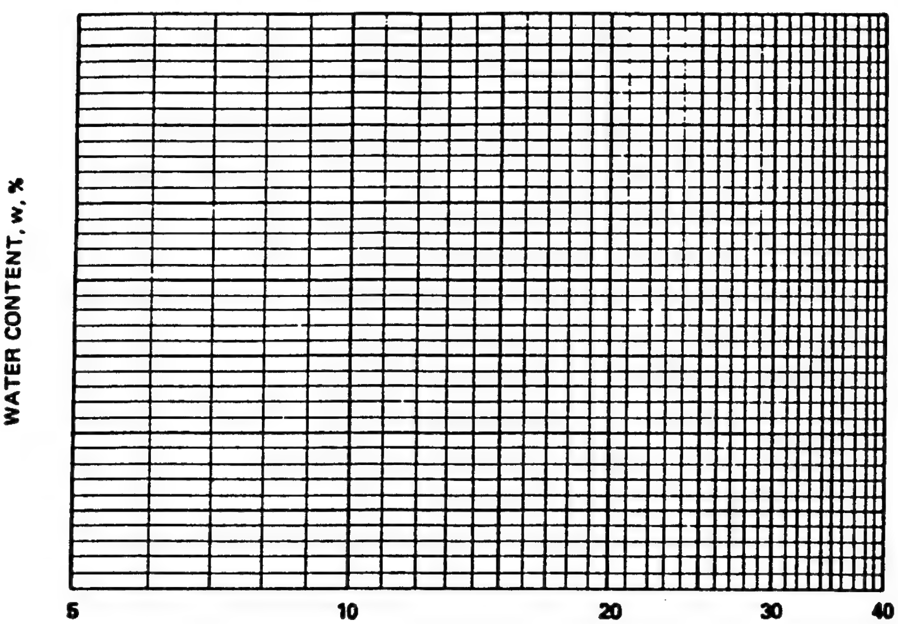
BORING NO. COELSB 0022 SAMPLE NO. Composite

LIQUID LIMIT

	RUN NO.		1	2	3	4	5	6
	TARE NO.		9	10				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		6.503	7.178				
	TARE PLUS DRY SOIL		5.383	5.915				
	WATER	W_w						
	TARE		1.528	1.538				
	DRY SOIL	W_s						
	WATER CONTENT, %	w	29.1	28.9				
	NUMBER OF BLOWS		23	27				

(SAVE H2O & SOIL)

28.8 29.1



LL 29.0

PL 16.1

PI 12.9

Symbol from plasticity chart CL

Med tough

PLASTIC LIMIT

	RUN NO.		1	2	3	4	5	NATURAL WATER CONTENT
	TARE NO.		11	12				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		3.631	3.77				
	TARE PLUS DRY SOIL		3.336	3.459				
	WATER	W_w						
	TARE		1.502	1.516				
	DRY SOIL	W_s						
	WATER CONTENT, %	w	16.1	16.0				
	PLASTIC LIMIT							

REMARKS

TECHNICIAN ______ COMPUTED BY ______ CHECKED BY ______

-14
M-15

GRAIN SIZE ANALYSIS

C

Date: 9-20-90
Project No.:
Project: ROCKY MOUNTAIN ARSENAL
Location of Sample: COELSB 0022
Sample Description: LIGHT BROWN
USCS:
AASHTO:
Liquid Limit:
Plastic Index:
Remarks: COMPOSITE 2.5', 5', 7.5', 10', 15', 20', 25', & 30' (SAVE H_2O & SOIL)

☒ Mechanical analysis
☐ Hydrometer analysis

Data Sheet 1 - Mechanical

	Initial Sample	After Wash
Dry Sample and Tare=		
Tare=		
Dry Sample Weight=	104.2	

Calculated -200=
Tare For Cumulative Weight Retained=

FN: 0 Font. % Passing
enter a formula, a value or text into the current cell

MECHANICAL ANALYSIS

U.S. STANDARD SIEVE SIZE(MM)	SIEVE NO.	SAMPLE WT.	% COARSER	% FINER
76.2	3 INCH	0.0	0.0	100.0
38.1	1 1/2 INCH	0.0	0.0	100.0
19.1	3/4 INCH	0.0	0.0	100.0
9.52	3/8 INCH	0.0	0.0	100.0
4.76	NO. 4	0.0	0.0	100.0
PAN		0.0	0.0	
TOTAL		0.0		
ACTOR		0.9597		
).10	2.00	0.0	0.0	100.0
. 20	0.84	1.0	1.0	99.0
. 40	0.42	4.7	4.5	95.5
. 80	0.177	16.7	16.0	84.0
.200	0.074	42.3	40.6	59.4
PAN		104.2	100.0	0.0

.er:
ue: 104.2
ksheet: mech2 Loc: r28c5 FN: 0 Font: Standard
TER - enter a formula, a value or text into the current cell

10 ~~18~~

19-A

LIQUID AND PLASTIC LIMIT TESTS

For use of this form, see EM 1110-2-1906.

BORROW #1 (A)

DATE 9-20-90

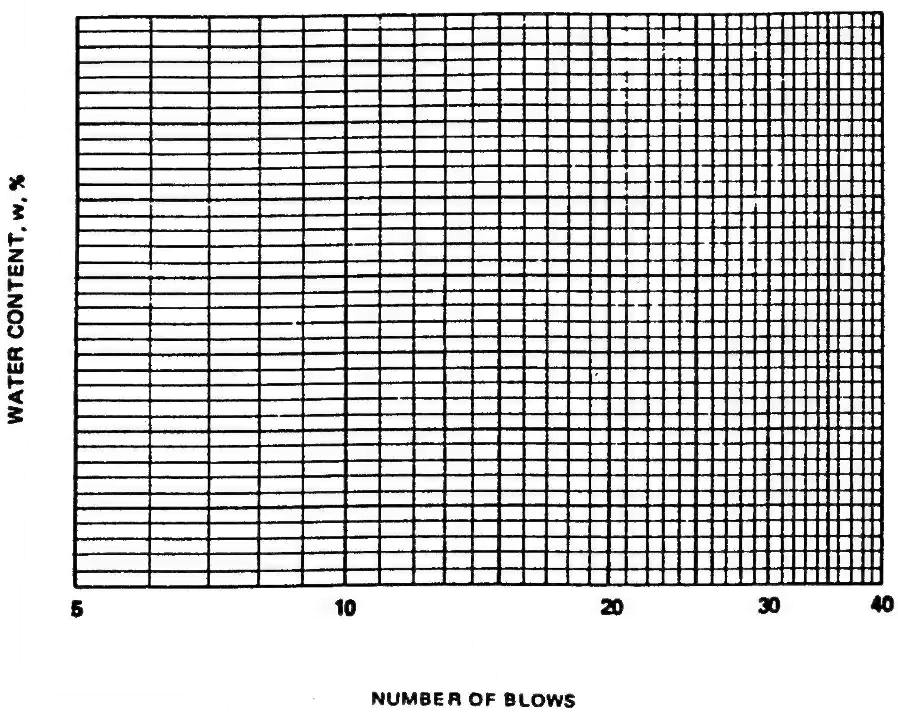
PROJECT ROCKY MOUNTAIN ARSENAL

BORING NO. 25 BORE 007 1'-6' SAMPLE NO.

LIQUID LIMIT

		RUN NO.	1	2	3	4	5	6
		TARE NO.	1	2				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		6.135	8.161				
	TARE PLUS DRY SOIL		4.948	6.464				
	WATER	W_w	7					
	TARE		1.524	1.54				
	DRY SOIL	W_s						
WATER CONTENT, %		w	34.7	34.6				
NUMBER OF BLOWS			23	26				

(SAVE 343 H_2O 344 & SOIL)



LL 34.6

PL 13.5

PI 21,1

Symbol from plasticity chart CL

Med tough

PLASTIC LIMIT

		RUN NO.	1	2	3	4	5	NATURAL WATER CONTENT
		TARE NO.	3	4				
WEIGHT IN GRAMS	TARE PLUS WET SOIL		3.486	3.053				
	TARE PLUS DRY SOIL		3.253	2.871				
	WATER	W_w						
	TARE		1.526	1.513				
	DRY SOIL	W_s						
WATER CONTENT, %		w	13.5	13.4				
PLASTIC LIMIT								

REMARKS

TECHNICIAN ______ COMPUTED BY ______ CHECKED BY ______

ENG FORM 1 JUN 65 3838 PLATE III-1

1-0-41
M-64

GRAIN SIZE ANALYSIS

BORROW # 1

A

Date: 9-20-90

Project No.: ____________

Project: ROCKY MOUNTAIN ARSENAL

Location of Sample: 25 BORE 007 1'-6'

Sample Description: BROWN

USCS: ____________ AASHTO: ____________

Liquid Limit: ______ Plastic Index: ______

Remarks: (SAVE H_2O & SOIL)

[X] Mechanical analysis

[ ] Hydrometer analysis

Data Sheet 1 - Mechanical

	Initial Sample	After Wash
Dry Sample and Tare=		
Tare=		
Dry Sample Weight=	113.9	
Calculated -200=		

Tare For Cumulative Weight Retained= ____________

Sieve	Weight	Tare	Cum.	%

MECHANICAL ANALYSIS

U.S. STANDARD SIEVE SIZE(MM)	SIEVE NO.	SAMPLE WT.	% COARSER	% FINER
76.2	3 INCH			
38.1	1 1/2 INCH	0.0	0.0	100.0
19.1	3/4 INCH	0.0	0.0	100.0
9.52	3/8 INCH	0.0	0.0	100.0
4.76	NO. 4	0.0	0.0	100.0
PAN		0.0	0.0	100.0
TOTAL		0.0	0.0	
FACTOR		0.0		
NO.10		0.8780		
NO. 20	2.00	1.0	0.9	99.1
NO. 40	0.84	6.2	5.4	94.6
NO. 80	0.42	15.3	13.4	86.6
NO.200	0.177	23.4	20.5	79.5
PAN	0.074	34.3	30.1	69.9
		113.9	100.0	0.0

Enter:
Value: 1
Worksheet: mech2 Loc: r23c5 FN: 0 Font: Standard
... into the current cell

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS

PROJECT RMA - LIME SETTLING BASINS	SHEET NO. 1 OF 2	
ITEM GROUND WATER INFILTRATION THRU SLURRY WALL - TIME CALCULATION	BY JMB	DATE 9/4/90
	CHKD. BY	DATE

REFS. : McWHORTER & SUNADA, GROUND-WATER HYDROLOGY AND HYDRAULICS, 198

EQUATIONS

FLOW VOLUME CALCS. BY JMC ON 5/18/90 - 5/21/90

GRADIENTS AND VOLUMES.

$Q = k\,i\,A$

Q = FLOW VOLUME

k = PERMEABILITY

i = GRADIENT

A = AREA OF FLOW

$v = \frac{Q}{nA} = \frac{\text{DISTANCE}}{\text{TIME}}$

v = SEEPAGE VELOCITY

n = POROSITY

SEEPAGE VELOCITY v IS USED TO CALCULATE THE TIME OF WATER MOVEMENT.

n OF BACKFILL NOT KNOWN BECAUSE COMPATABILITY TESTING NOT COMPLETE. TABLE 4-2 OF HOLTZ AND KOVACS AN INTRO. TO GEOTECHNICAL ENGINEERING (1981) LISTS TYPICAL n FOR SILTY SAND AS 47% (LOOSE) TO 23% (DENSE)

USE AVG. $n = \frac{47+23}{2} = 35\% = 0.35$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 1	OF 2
ITEM		BY JMB	DATE 9/4/90
		CHKD. BY	DATE

SOUTH WALL

AVG. WATER LEVEL OUTSIDE WALL = 5250

AVG. WATER LEVEL INSIDE WALL = 5247

AVG. HEAD = $\frac{3}{2}$ = 1.5'

$i = \frac{1.5}{3} = 0.50$

$A = 9100$ FT^2 $k = .00028$ FT/DAY

$Q = .00028(.50)(9100) = 1.274$ FT^3/DAY

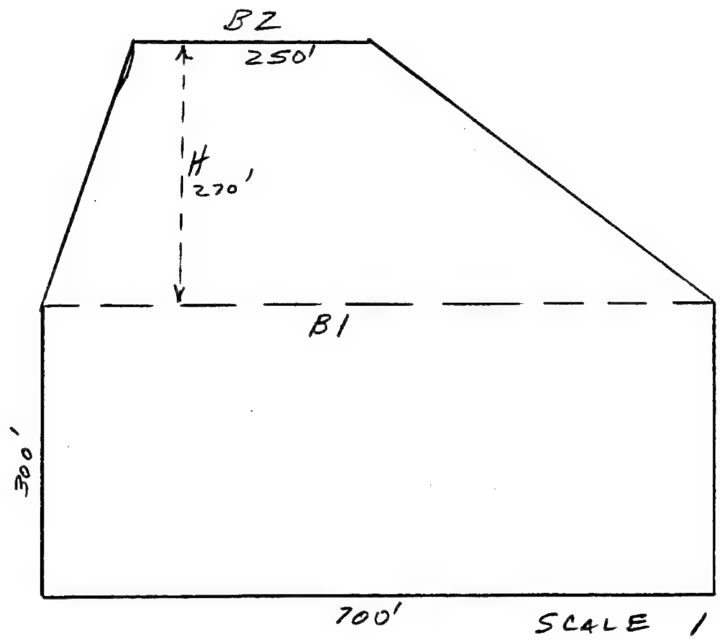
$v = \frac{Q}{nA} = \frac{1.274}{(.35)(9100)} = .0004$ FT/DAY

$t = \frac{3}{.0004 \text{ FT/DAY}}$ = 7,500 DAYS

= 20.5 YEARS

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA LIME SETTLING BASINS	SHEET NO. 1	OF 2
ITEM CALCULATION OF INITIAL WATER LEVEL & PORE WATER VOLUMES	BY JMZ	DATE 5/18/90
	CHKD. BY	DATE

WITHIN ISOLATION CELL



SCALE 1" = 200'

AREA TRAPAZOID $= \frac{B1 + B2}{2} \times H$

$= \frac{700' + 250'}{2} \times 270'$

$= 128{,}250\ ft^2$

AREA RECTANGLE $= L \times W$

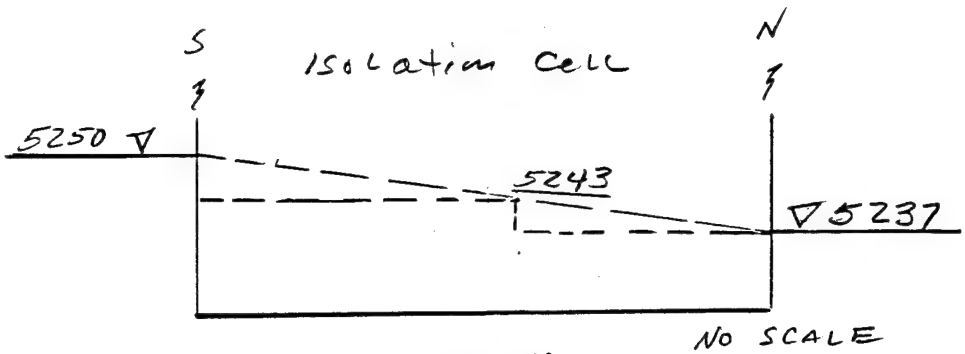
$= 700' \times 300'$

$= 210{,}000\ ft^2$

TOTAL AREA OF CELL $= 128{,}250\ FT^2 + 210{,}000\ ft^2$

$= 338{,}250\ ft^2$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA LIME SETTLING BASINS		SHEET NO. 2	OF 2
ITEM CALCULATION OF STABILIZED WATER LEVEL WITHIN CELL AFTER		BY JMZ	DATE 5/18/90
		CHKD. BY	DATE



Estimated porosity = 35%

VOLUME VOIDS TRAP SECTION $= 0.35 \times (128{,}250)\left(\frac{6}{2}\right)$

$= 134{,}663\ ft^3$

VOLUME VOIDS RECTANGLE $= 0.35 \times (210{,}000)\left(\frac{7}{2}\right)$

$= 257{,}250\ ft^3$

EXCESS VOL VOIDS RECT − TRAP = 122,587

TOTAL VOL VOIDS PER 1' DEPTH IN CELL

$= 0.35 \times (338{,}250)(1)$

$= 118{,}388\ ft^3$

TOTAL RISE ABOVE EL 5243

$= \frac{122{,}587}{118{,}388}$

= 1.04 FT ROUND TO 1.0'

EL STABILIZED WL IN CELL = 5243 + 1

= 5244

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - Lime Settling Basins		SHEET NO. 1	OF 8
ITEM Ground Water Infiltration through Slurry Wall - Volume Calculation		BY JMC	DATE 5-21-90
		CHKD. BY	DATE

Formula for Volume Calculations

$$Q = K\,I\,A$$

Q = volume of seepage through bentonite slurry wall

K = hydraulic conductivity of slurry wall

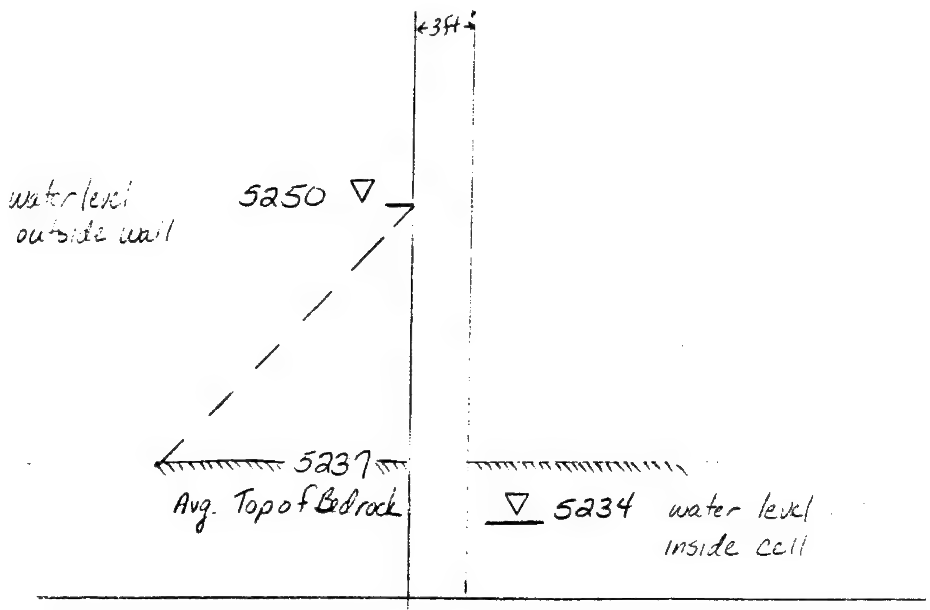
I = gradient

A = area of slurry wall

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA Lime Settling Basins	SHEET NO. 2 OF 8	
ITEM Ground Water Infiltration through Slurry Walls - Volume Calculations	BY JMC	DATE 5-18-90
	CHKD. BY	DATE

1" = 10'

South Wall



$Q = KIA$

$K = .00028 \text{ ft/day} = 10^{-7} \text{ cm/sec}$

$I = \frac{13}{2} \div 3 = 2.17$

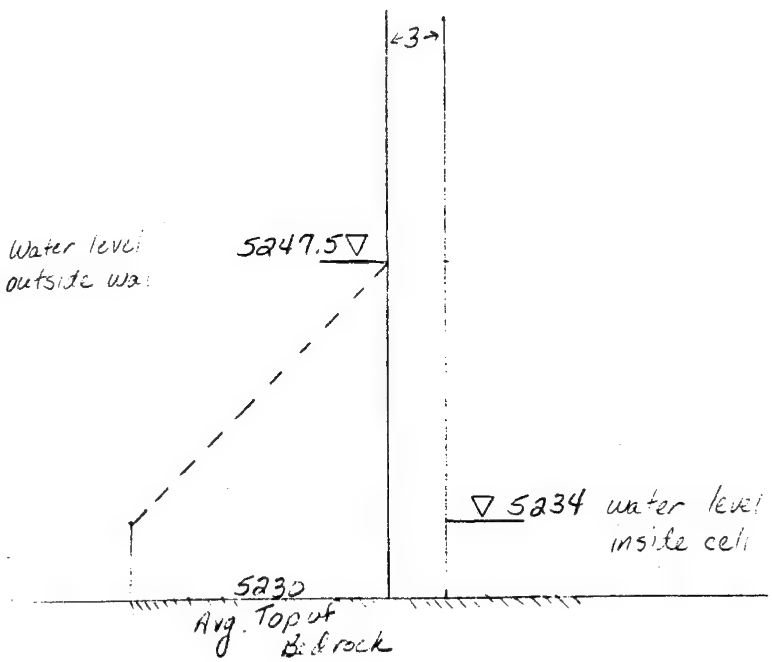
$A = 13 \times 700 = 9100 \text{ ft}^2$

$Q_s = .00028 \times 2.17 \times 9100 = 5.53 \text{ ft}^3/\text{day}$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA – Lime Settling Basins		SHEET NO. 3 OF 8	
ITEM Ground Water Infiltration through Slurry Walls – Volume Calculations		BY JMC	DATE 5-18-90
		CHKD. BY	DATE

1" = 10'

East Wall



$Q = KIA$

$K = .00028 \text{ ft/day} = 10^{-7} \text{ cm/sec}$

$I = \frac{13.5}{2} \div 3 = 2.25$

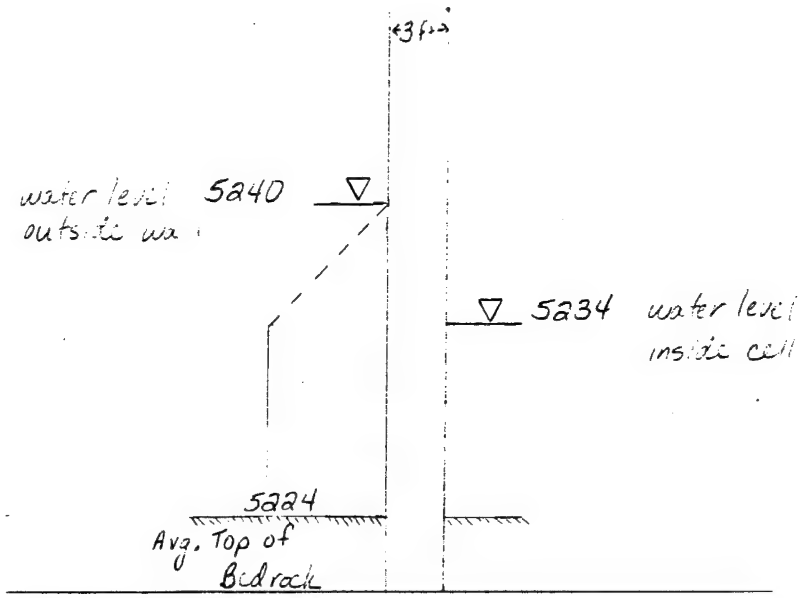
$A = 17.5 \times 300 = 5250 \text{ ft}^2$

$Q_E = .00028 \times 2.25 \times 5250 = 3.31 \text{ ft}^3/\text{day}$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA - Lime Settling Basins	SHEET NO. 4 OF 8	
ITEM Ground Water Infiltration through Slurry Wall - Volume Calculations	BY JMC	DATE 5-18-90
	CHKD. BY	DATE

1" = 10'

North East Wall



$Q = KIA$

$K = .00028 \text{ ft/day} = 10^{-7} \text{ cm/sec}$

$I = \frac{6}{2} \div 3 = 1$

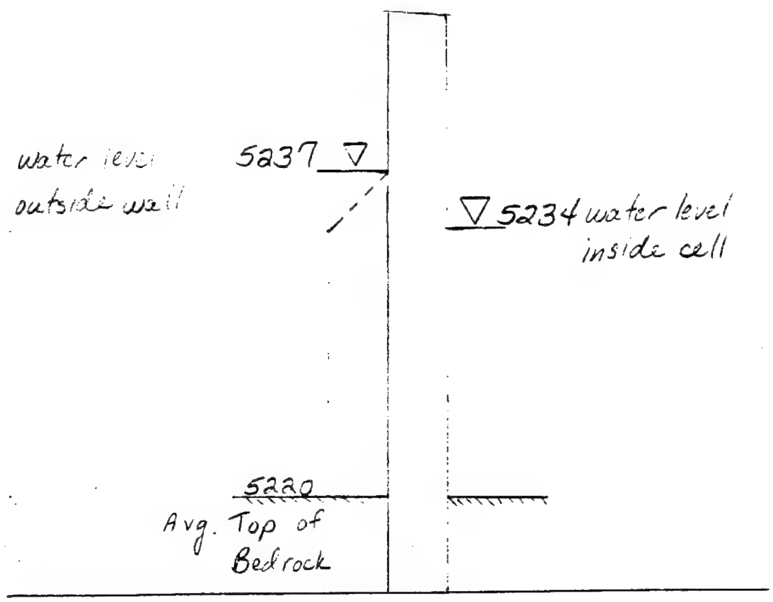
$A = 16 \times 460 = 7360 \text{ ft}^2$

$Q_{NE} = .00028 \times 1 \times 7360 = 2.06 \text{ ft}^3/\text{day}$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA – Lime Settling Basins		SHEET NO. 5 OF 8	
ITEM Ground Water Infiltration through Slurry Wall – Volume Calculations		BY JMC	DATE 5-18-90
		CHKD. BY	DATE

1" = 10'

North Wall



$$Q = KIA$$

$$K = .00028 \text{ ft/day} = 10^{-7} \text{ cm/sec}$$

$$I = \frac{3}{2} \div 3 = 0.5$$

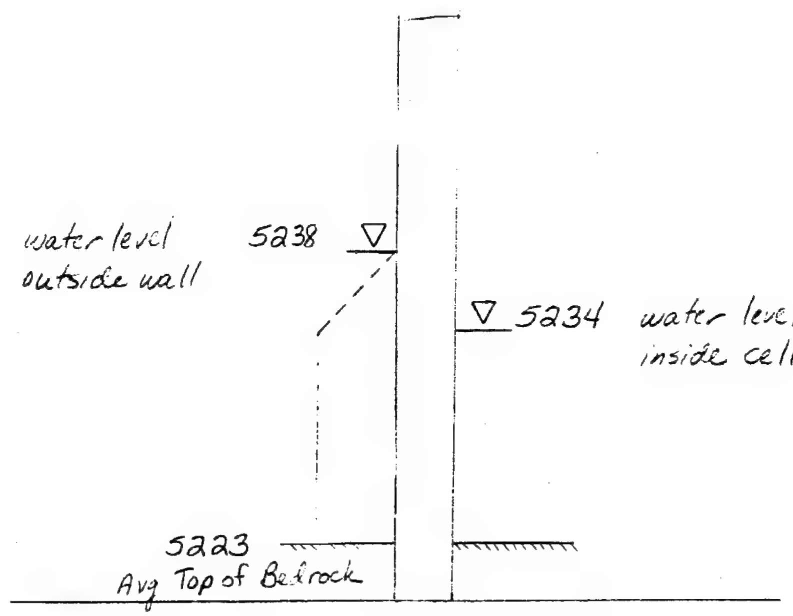
$$A = 17 \times 250 = 4250 \text{ ft}^2$$

$$Q_N = .00028 \times .5 \times 4250 = .595 \text{ ft}^3/\text{day}$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA - Lime Settling Basins	SHEET NO. 6 OF 8	
ITEM Ground Water Infiltration through Slurry Walls - Volume Calculations	BY JMC	DATE 5-18-90
	CHKD. BY	DATE

1" = 10'

Northwest Wall



$$Q = KIA$$

$$K = .00028 \text{ ft/day} = 10^{-7} \text{ cm/sec}$$

$$I = \frac{4}{2} \div 3 = .66$$

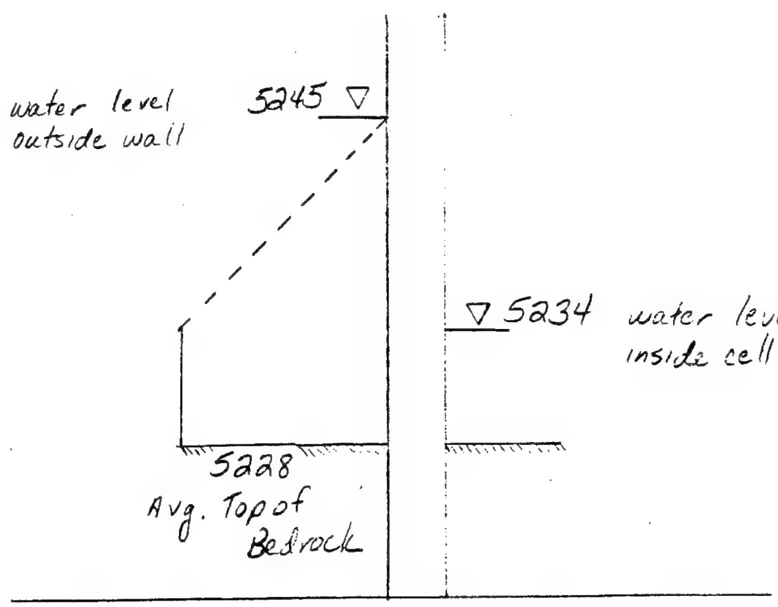
$$A = 15 \times 290 = 4350 \text{ ft}^2$$

$$Q_{NW} = .00028 \times 0.66 \times 4350 = 0.812 \text{ ft}^3/\text{day}$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - Lime Settling Basins		SHEET NO. 7	OF 8
ITEM Ground Water Infiltration through Slurry Wall - Volume Calculations		BY JMC	DATE 5-18-90
		CHKD. BY	DATE

1" = 10'

West Wall



$Q = KIA$

$K = .00028\ ft/day = 10^{-7}\ cm/sec$

$I = \frac{11}{2} \div 3 = 1.83$

$A = 17 \times 300 = 5100\ ft^2$

$Q_w = .00028 \times 5100 \times 1.83 = 2.62\ ft^3/day$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS

PROJECT RMA - Lime Settling Basins	SHEET NO. 8 OF 8	
ITEM Ground Water Infiltration through Slurry Wall - Volume Concentrators	BY JMC	DATE 5-21-90
	CHKD. BY	DATE

$$Q_{TOT} = Q_S + Q_E + Q_{NE} + Q_N + Q_{NW} + Q_W$$

$Q_S = 5.53\ ft^3/day$

$Q_E = 3.31\ ft^3/day$

$Q_{NE} = 2.06\ ft^3/day$

$Q_N = 0.60\ ft^3/day$

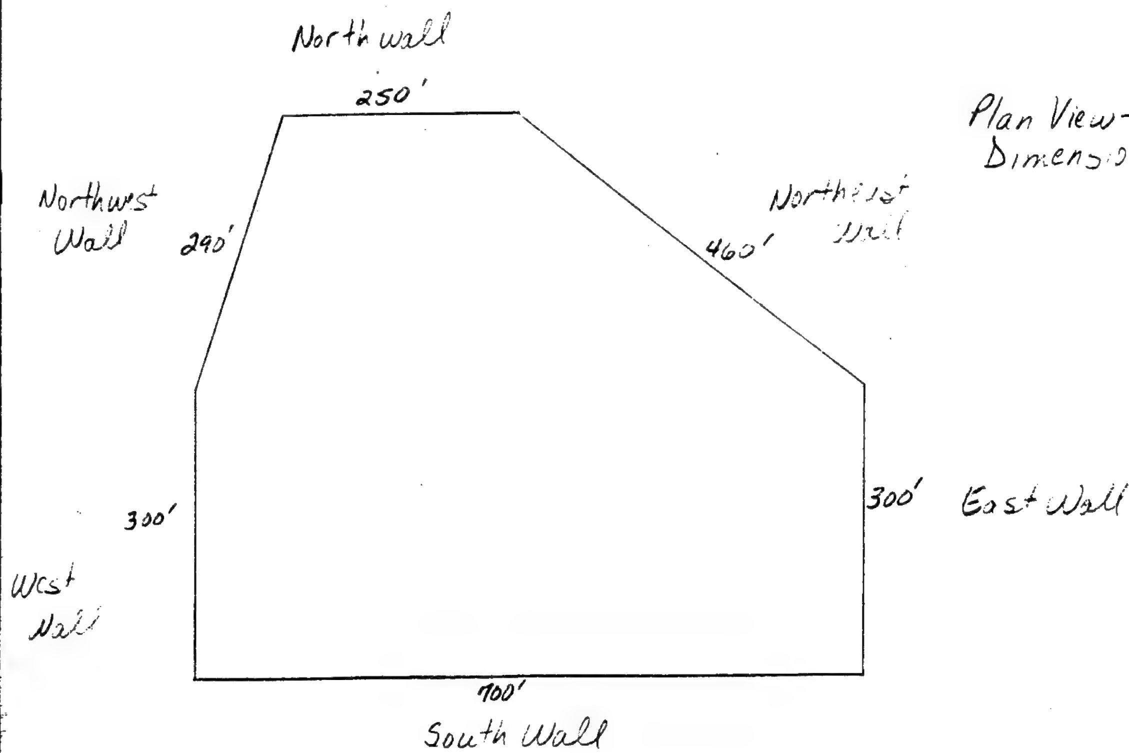
$Q_{NW} = 0.81\ ft^3/day$

$Q_W = 2.62\ ft^3/day$

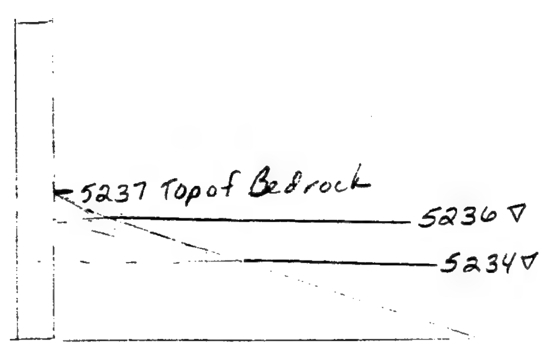
$Q_{TOT} = 14.93\ ft^3/day$

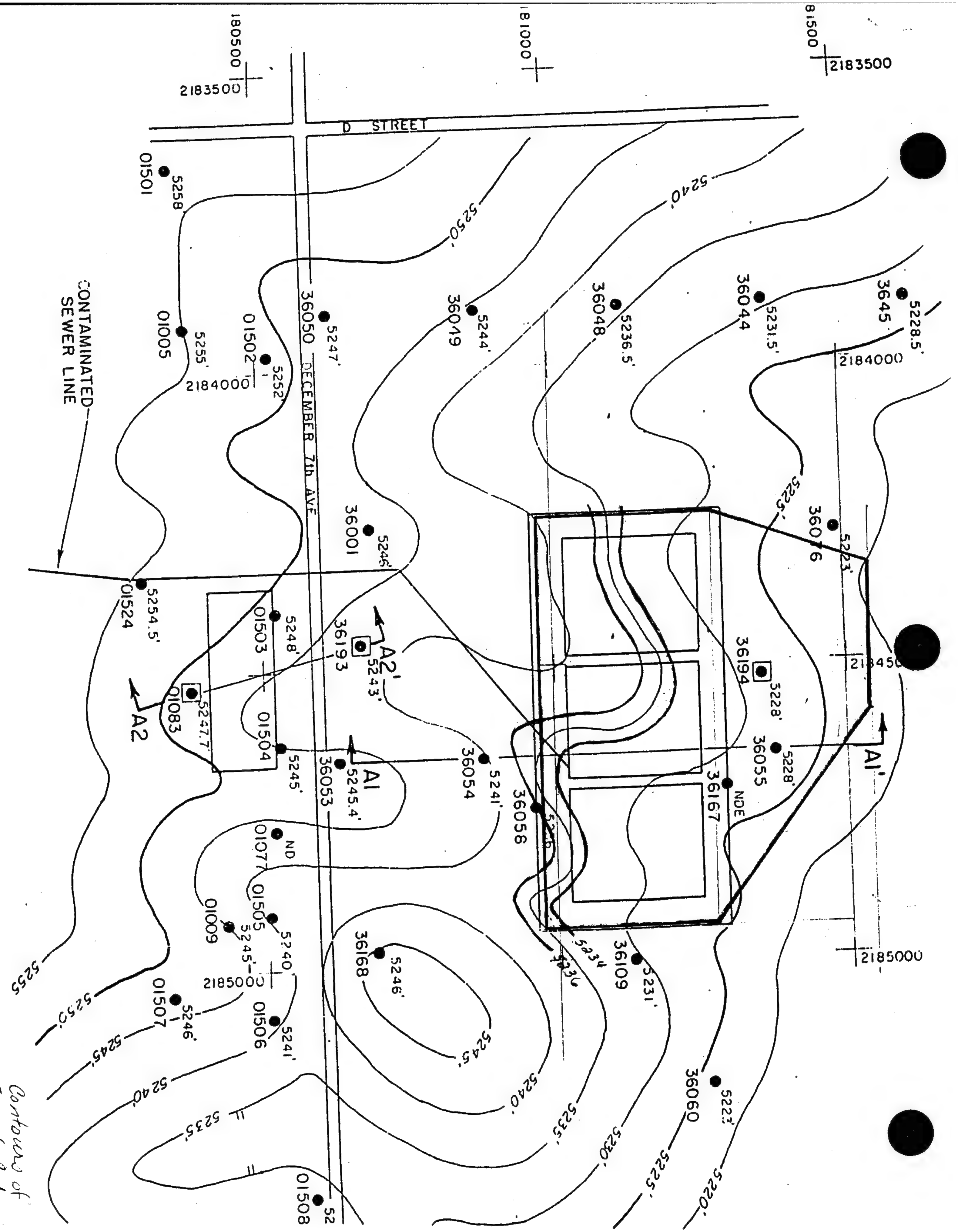
$14.93\ ft^3/day = 0.42\ m^3/day = 111.68\ gal/day = .08\ gal/min$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - Lime Settling Basins		SHEET NO. 1	OF 4
ITEM Dimensions used to Calculate Surface Area of Cell at Elevations 5236 + 5234		BY JMC	DATE 5-21-90
		CHKD. BY	DATE



Plan View - Dimensions of Cell




D STREET
DECEMBER 7th AVE
CONTAMINATED SEWER LINE
2183500
2184000
2184500
2185000
180500
181000
181500
A1
A1'
A2
A2'
01501
01005
01502
01503
01504
01524
01083
01077
01505
01009
01507
01506
01508
36050
36019
36048
36044
3645
36001
36193
36194
36054
36053
36058
36055
36167
36076
36168
36109
36060
5258
5255'
5252'
5247'
5244'
5236.5'
5231.5'
5228.5'
5245'
5254.5'
5248'
5243'
5247.7'
5228'
5241'
5245.4'
5223'
5246'
5240'
5231'
5255
5250'
5240'
5235'
5230'
5225'
5220'

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - LIME SETTLING BASINS.		SHEET NO. 2	OF 4
ITEM SURFACE AREA OF CELL AT 5236 & 5234 (SCALE FACTOR - 200 x 200 = 40,000		BY RJMc	DATE 5/21/90
		CHKD. BY	DATE

El. 5234 = 6.35 □" x 40,000 = 174,000 □'

El. 5236 = 7.40 □" x 40,000 = 296,000 □'

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA - LIME SETTLING BASINS	SHEET NO. 3 OF 4	
ITEM Volume Calculations from surface areas at Elevations 5236 & 5234	BY JMC	DATE 5-21-90
	CHKD. BY	DATE

At Elevation 5234 → Surface Area = length x width = 174,000 ft^2

Volume = 174,000 ft^2 x 2 ft = 348,000 ft^3

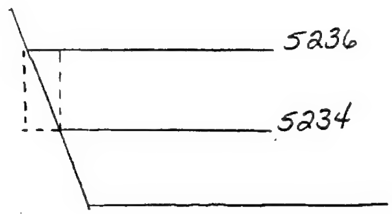
Pore Volume = 348,000 ft^3 x 35% = 121,800 ft^3

At Elevation 5236 → Surface Area = length x width = 296,000 ft^2

Volume = 296,000 ft^2 x 2 ft = 592,000 ft^3

Pore Volume = 592,000 ft^3 x 35% = 207200 ft^3

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA - Lime Settling Basins	SHEET NO. 4	OF 4
ITEM Average Volume between 5236 + 5234 Elevations	BY JMC	DATE 5-21-90
	CHKD. BY	DATE



Volume at 5236' = 296,000 ft^2 x 2 ft = 592,000 ft^3

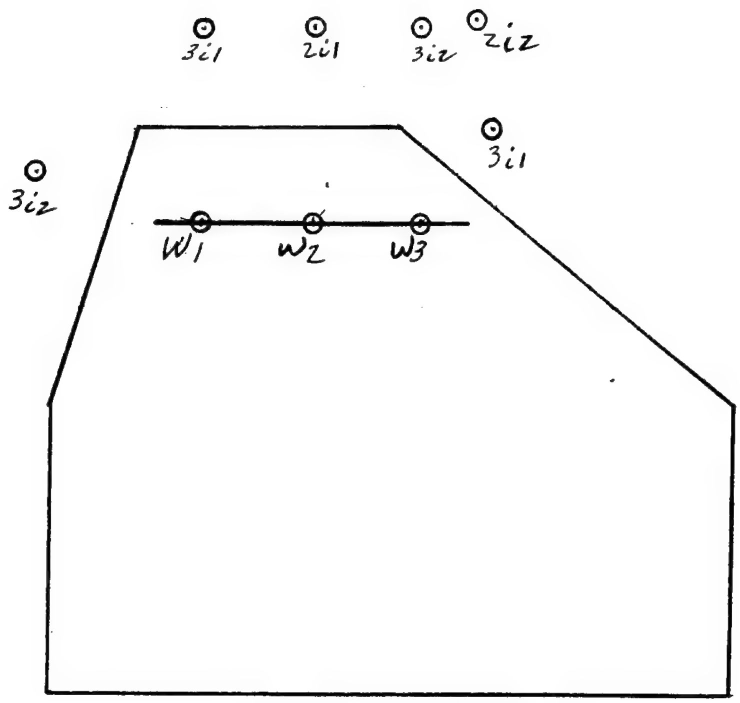
Volume at 5234' = 174,000 ft^2 x 2 ft = 348,000 ft^3

Average Volume = 592,000
+348,000
940,000 ÷ 2 = 470,000 ft^3

Average Pore Volume = 470,000 ft^3 x 35% = 164,500 ft^3

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Lime Settling Basins	SHEET NO. 1 OF 3	
ITEM Analysis of G.W. Withdrawal by Wells.	BY JMZ	DATE
	CHKD. BY	DATE



Scale 1" = 200'

Bottom of Aquifer EL = 5227
G.W. EL = 5239
Hyd. Cond = 1×10^{-4} cm/sec = 0.283'/day.

$$Q = \frac{\pi K (H^2 - h^2)}{\ln_e \frac{R}{r}}$$

Where
Q = Pumping Rate ft^3/Day
K = Hyd. Cond. Ft/Day
H = Saturated Thickness Ft
h_w = Height of Water in Well Ft
R = Assumed Radius of Influence Ft
r = Radius of Well Ft

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT LSB		SHEET NO. 2 OF 3	
ITEM ANAL. GW WITHDRAWAL BY WELLS		BY JMZ	DATE
		CHKD. BY	DATE

$H = 12.0'$

$h_w = 12.0 - [(12.0) \times 60\%] = 4.8$

$$Q = \frac{(3.14)(0.283)(12.0^2 - 4.8^2)}{\ln_e \frac{500}{0.5}}$$

$Q = 15.6 \text{ Ft}^3/\text{DAY} = 0.08 \text{ gpm}$

THIS VOLUME IS TOO SMALL TO PUMP EVEN DISREGARDING BOUNDARY AND INTERFERENCE EFFECTS

CALCULATION OF THEORETICAL DRAWDOWN FOR WELL #3 INCLUDING BOUNDARY AND INTERFERENCE EFFECTS.

$$h_{w3} = \sqrt{H^2 - \left[\frac{Q \ln_e \frac{R}{r}}{\pi K}\right]}$$

$$\text{Let } C = \frac{Q}{\pi K} = \frac{15.6}{(3.14)(0.283)} = 17.6$$

FOR BOUNDARY EFFECT NE OF W_3 FOR IMAGE WELL W_{3i_1} AT $r = 120'$

$$h_{w_{3i_1}} = \sqrt{144 - \left[(17.6) \ln_e \frac{500}{120}\right]} = \sqrt{144 - 25.1} = 10.9'$$

$\therefore$ DD DUE TO NE BOUNDARY $= 12.0' - 10.9' = 1.1'$

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET		CORPS OF ENGINEERS
PROJECT LSB	SHEET NO. 3 OF 3		
ITEM ANAL G.W. WITHDRAWAL BY WELLS	BY JMZ	DATE	
	CHKD. BY	DATE	

FOR BOUNDARY EFFECT N. OF W_3 FOR IMAGE WELL W_{3i_2} AT $r = 200'$

$$h_{w_{3i_2}} = \sqrt{144 - \left[(17.6)\ln_e \frac{500}{200}\right]} = \sqrt{144 - 16.1} = 11.3'$$

∴ DD DUE TO N. BOUNDARY = $12.0' - 11.3' = 0.7'$

FOR WELL INTERFERENE FROM W_2 AT $r = 112.5'$

$$h_{w_2} = \sqrt{144 - \left[(17.6)\ln_e \frac{500}{112.5}\right]} = \sqrt{144 - 26.3} = 10.8'$$

∴ DD DUE TO W_2 INTERFERENCE = $12.0' - 10.8' = 1.2'$

FOR WELL INTERFERENCE FROM W_1 AT $r = 225'$

$$h_{w_1} = \sqrt{144 - \left[(17.6)\ln_e \frac{500}{225}\right]} = \sqrt{144 - 14.1} = 11.4'$$

∴ DD DUE TO W_1 INTERFERENCE = $12.0' - 11.4' = 0.6'$

TOTAL DD = $7.2' + 1.1' + 0.7' + 1.2' + 0.6' = 10.8'$

ASSUME 80% WELL EFFICIENCY = $\frac{10.8}{.8} = 13.5'$

AVAILABLE DD $12.0' <$ CALCULATED DD $13.5'$

∴ NOT SUFFICIENT AVAILABLE DD TO PRODUCE 0.08 gpm

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT LSB		SHEET NO. 1 OF 1
ITEM HYDRAULIC CONDUCTIVITY DETERMINATION		BY JNZ / DATE
		CHKD. BY / DATE

FROM SLUG TESTS

HOLE #34 AVE 3.4×10^{-4} ft/min

" 35 " 2.3×10^{-4} "

5.7×10^{-4} "

AVE of AVE $\frac{5.7}{2} \times 10^{-4}$ ft/min $= 2.8 \times 10^{-4}$ ft/min

2.8×10^{-4} ft/min $\times$ 12 in/ft $\times$ 2.54 cm/in $\div$ 60 sec/min =

1.4×10^{-4} cm/sec

For conservative approach use 1.0×10^{-4}

1.0×10^{-4} cm/sec $\div$ 2.54 cm/in $\div$ 12 in/ft $\times$ 60 sec/min

$\times$ 1440 min/day = 0.283 ft/day

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT LIME SETTLING BASINS	SHEET NO. 1	OF 4
ITEM CALCULATION OF FLOW FROM HORIZONAL DRAIN	BY JMZ	DATE
	CHKD. BY	DATE

1. Utilizing Ibrahim and Brutsaert (1965) equations as discussed by Freeze and Cherry (1979). See graphs and diagrams by Freeze and Cherry as reproduced in this appendix. Construction of the graph for average flows from the drain utilize these graphs and diagram, and equations shown in the appendix.

For a horizontal drain located at an average depth below the water table of 11 feet, a length of 325 feet, the following equations are used.

$$\tau = \frac{KH}{S_y L^2} t$$

where τ = dimensionless time
K = hydraulic conductivity
H = depth of impermeable base below water table
S_y = specific yield
L = distance of drain (seepage face) from impermeable barrier.
t = time

and $$\gamma = \frac{S_y L}{KH^2} q$$

where γ = dimensionless discharge
q = rate of flow from one side of the drain at time t.

Solving for q

$$q = \frac{\gamma K H^2}{S_y L}$$

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT LSB		SHEET NO. 2 OF 4	
ITEM Calculation of Flow from horiz. drain		BY JMZ	DATE
		CHKD. BY	DATE

From equation $\tau = \frac{KH}{S_y L^2} t$ For North side

Let $C = \frac{KH}{S_y L^2}$ For $K = 0.283$ ft/day

$H = 11$ ft

then $\tau = Ct$ $L = 100$ ft

$S_y = 0.2$ (dimensionless)

Determine values of τ and γ for various time intervals

$$C = \frac{(0.283)(11)}{(0.2)(100)^2} = 0.0016$$

FROM GRAPH

$\tau = (0.0016)(10) = 0.016$ $\gamma = 4.9$ (est)

$\tau = (0.0016)(20) = 0.032$ $\gamma = 3.0$ (est)

$\tau = (0.0016)(100) = 0.16$ $\gamma = 0.85$

$\tau = (0.0016)(200) = 0.32$ $\gamma = 0.56$

$\tau = (0.0016)(500) = 0.80$ $\gamma = 0.27$

$\tau = (0.0016)(1000) = 1.6$ $\gamma = 0.13$

$\tau = (0.0016)(1500) = 2.4$ $\gamma = 0.076$

$\tau = (0.0016)(2000) = 3.2$ $\gamma = 0.047$

Determine values of q at time intervals γ_t

$q = \frac{\gamma K H^2}{S_y L}$ Let $C = \frac{KH^2}{S_y L} = \frac{(0.283)(11)^2}{(0.2)(100)} = 1.7$

$q = (4.9)(1.7) = 8.33$ ft^3/day/ft 10 days

$q = (3.0)(1.7) = 5.10$ " " " 20 "

$q = (0.85)(1.7) = 1.45$ " " " 100 "

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT LSB	SHEET NO. 3 OF 4	
ITEM Calculation of Flow from Horizonatal drain	BY JMZ	DATE
	CHKD. BY	DATE

$q = (0.56)(1.7) = 0.95 \text{ ft}^3/\text{day}/\text{ft}$ 200 days

$q = (0.27)(1.7) = 0.46$ " 500 "

$q = (0.13)(1.7) = 0.02$ " 1000 "

$q = (0.076)(1.7) = 0.13$ " 1500 "

$q = (0.047)(1.7) = 0.08$ " 2000 "

Time to reach el 5234 at North wall

$H = 5237 - 5225 = 12'$

$h = 5234 - 5225 = 9$

$\frac{h}{H} = \frac{9}{12} = 0.75$

$\frac{x}{L} = 1$ τ from graph $= 0.39$

$$t = \frac{\tau S_y L^2}{K H} = \frac{(0.39)(0.2)(100)^2}{(0.283)(12)} = 230 \text{ days}$$

Ave Flow For 230 days (from graph) North side

# days	Flow Rate	Total Ave Flow
10	12.0 (EST)	120
10	6.7	67
80	3.3	264
100	1.2	120
30	0.9	27
230		598 ft³/ft of drain

$\frac{598}{230} = 2.6 \text{ ft}^3/\text{day}/\text{ft}$ of drain Ave Flow From NORTH side

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT LSB		SHEET NO. 4	OF 4
ITEM Calculation of flow from Horiz drain		BY JMZ	DATE
		CHKD. BY	DATE

For total average flow from the drain multiply flow from north side by 2 and length of drain.

$2.6\ ft^3/day/ft \times 2 \times 325\,ft = 1690\ ft^3/day$

This is equivalent to:

$1690\ ft^3/day \times 7.48\ gal/ft^3 \div 1440\ min/day = 8.8\ gpm$

Since boundary effects are not considered at the ends of the drain, and equations model flow from a free face, the flow rate from the drain will be less than 8.8 gpm. Recommend initial pumping rate from extraction system be 5.0 gpm.

Initial time required to reach elev 5234 at North wall pumping at 5gpm:

Volume to be pumped $= 1690\ ft^3/day \times 230\,days$
$= 388{,}700\ ft^3$

230 days	@ 5gpm =	$221{,}000\ ft^3$ (rounded)
396 days	@ 2.2 gpm =	167,700
626		388,700

Time to reach elev 5234 @ North wall

$\frac{626\ days}{365\ days/yr} = 1.7$ years.

Total volume remaining in cell above elev 5234

= 164,500 between el 5234 & 5236
+ 947,104 between el 5236 & 5244
− 388,700 amount drained in 1.7 years
722,904

Total time to drain at ave. $0.36\ ft^3/day/ft \times 325\,ft$

$= \frac{722{,}904}{117} = 6179$ days $= \frac{6179}{365} = 16.9 \approx 17$ years.

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT LSB		SHEET NO. 1	OF 1
ITEM EQUATIONS, GRAPHS AND DIAGRAM FOR DRAIN FLOW CALCULATIONS FROM FREEZE AND CHERRY (1979)		BY	DATE
		CHKD. BY	DATE

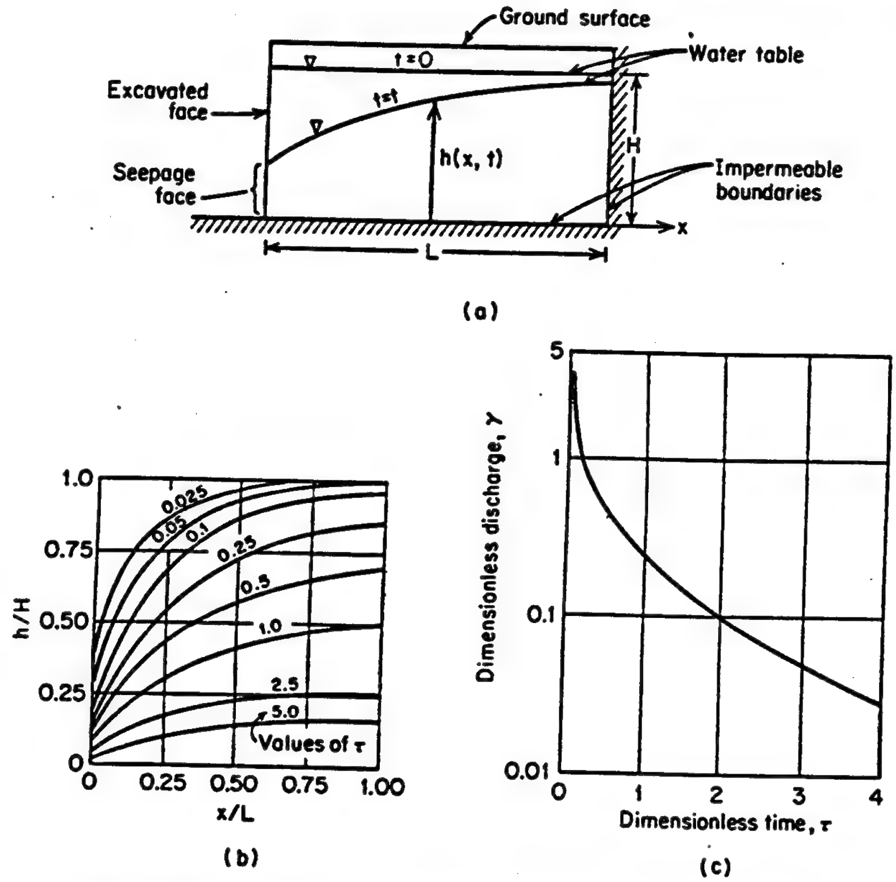


Figure 10.18 Prediction of groundwater inflows into an excavation (after Ibrahim and Brutsaert, 1965).

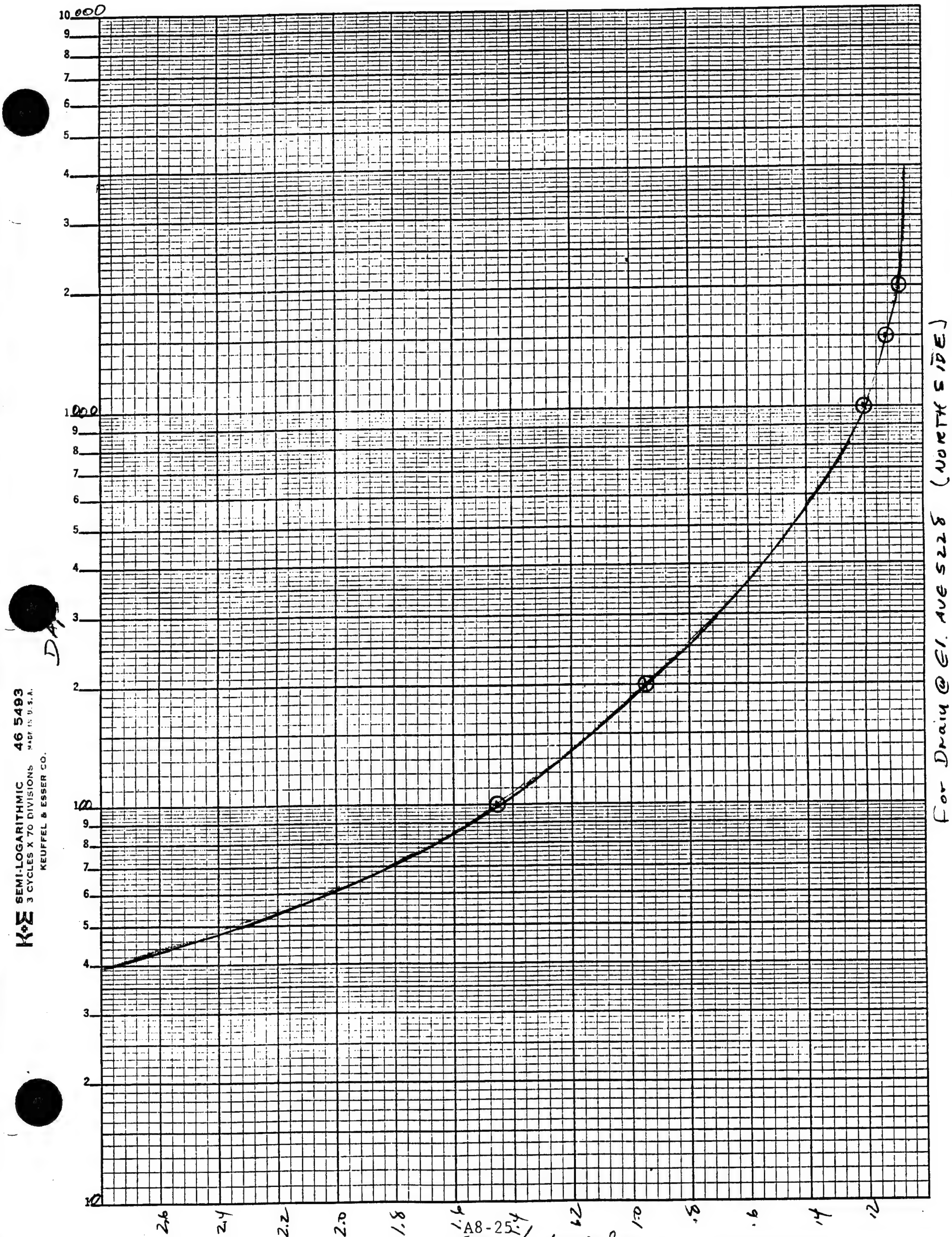
Figure 10.18(b) shows the transient response of the water table, plotted as dimensionless drawdown, h/H, versus dimensionless distance, x/L. The parameter τ is a dimensionless time given by

$$\tau = \frac{KH}{S_y L^2} t \qquad (10.19)$$

where H and L are defined by Figure 10.18(a), K and S_y are the hydraulic conductivity and specific yield of the aquifer, and t is time. In Figure 10.18(c), the dimensionless discharge γ, defined by

$$\gamma = \frac{S_y L}{KH^2} q \qquad (10.20)$$

is plotted against τ. The outflow $q = q(t)$ is the rate of flow (with dimensions L^3/T) into the excavation from the seepage face, per unit length of excavated face per-



10,000
1,000
100
10
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
For Drain @ El. AVE 522.8 (NORTH SIDE)
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT LSB		SHEET NO. 1	OF 1
ITEM Calculated time to reach stabilized (non-pumping) water level within the cell		BY JMZ	DATE
		CHKD. BY	DATE

$Q = KIA$

$K = 1 \times 10^{-4}$ cm/sec $= 0.283$ ft/day

$I = \frac{6-0}{300}'$

A = Area of discharging aquifer = 700' width x 14' depth at midpoint = 9800 ft^2

V = Volume to be filled per 1' depth (essentially confined to trapezoidal section =

$\frac{128,250}{2} \times 35\%$ porosity $= 22,444$ ft^3

a) $Q = (0.283)(\frac{6}{300})(9800) = 55.5$ ft^3/day

$t = \frac{V}{Q} = \frac{22,444}{55.5} =$ 404 days

b) $Q = (0.283)(\frac{5}{300})(9800) = 46$ ft^3/day

$t = \frac{22,444}{46} =$ 488 days

c) $Q = (0.283)(\frac{4}{300})(9800) = 37$ ft^3/day

$t = \frac{22,444}{37} =$ 606 days.

d) $Q = (0.283)(\frac{3}{300})(9800) = 27.7$ ft^3/day.

$t = \frac{22,444}{27.7} =$ 810 days

e) $Q = (0.283)(\frac{2}{300})(9800) = 18.5$ ft^3/day

$t = \frac{22,444}{18.5} =$ 1,213 days

f) $Q = (0.283)(\frac{1}{300})(9800) = 9.2$ ft^3/day

$t = \frac{22,444}{9.2}$ 2,440 day

5,961

$\frac{5961}{365} = 16.3$ years.

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS

PROJECT LSB	SHEET NO. / OF	
ITEM SAND FILTER DESIGN FOR DRAIN EM 1110-2-1901	BY JMZ	DATE
	CHKD. BY	DATE

Calculated Filter

FM = Filter Material
PS = Protected Soil

Piping

Max $\frac{D_{15FM}}{D_{85PS}} = \frac{1.6}{0.42} = 3.8 < 5$

Min $\frac{D_{15FM}}{D_{85PS}} = \frac{0.24}{0.17} = 1.4 < 5$

Max $\frac{D_{50FM}}{D_{50PS}} = \frac{3.4}{0.17} = 20 < 25$

Min $\frac{D_{50FM}}{D_{50PS}} - \frac{0.5}{0.03} = 17 < 25$

Permeability

Max $\frac{D_{15FM}}{D_{15PS}} = \frac{1.6}{0.04} = 40 > 5$

Min $\frac{D_{15FM}}{D_{15PS}} = \frac{0.24}{0.005} = 48 > 5$

SLOT SIZE FOR THE DRAIN

$\frac{D_{50FM(AVE)}}{\text{SLOT WIDTH}} = \frac{2.0}{0.5} = 4 > 1.2$

0.5 mm is equivalent to a # 20 SLOT = 0.020"

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT LSB		SHEET NO. 2 OF	
ITEM SAND FILTER DESIGN FOR DRAIN EM 1110-2-1901		BY JMZ	DATE
		CHKD. BY	DATE

ASTM C-33 FINE AGGREGATE FOR CONCRETE

PIPING

Max $\frac{D_{15FM}}{D_{85PS}} = \frac{0.38}{0.42} = 0.9 < 5$

Min $\frac{D_{15FM}}{D_{85PS}} = \frac{0.17}{0.17} = 1.0 < 5$

Max $\frac{D_{50FM}}{D_{50PS}} = \frac{1.3}{0.17} = 7.6 < 25$

Min $\frac{D_{50FM}}{D_{50PS}} = \frac{0.48}{0.03} = 16 < 25$

Permeability

Max $\frac{D_{15FM}}{D_{15PS}} = \frac{0.38}{0.04} = 9.5 > 5$

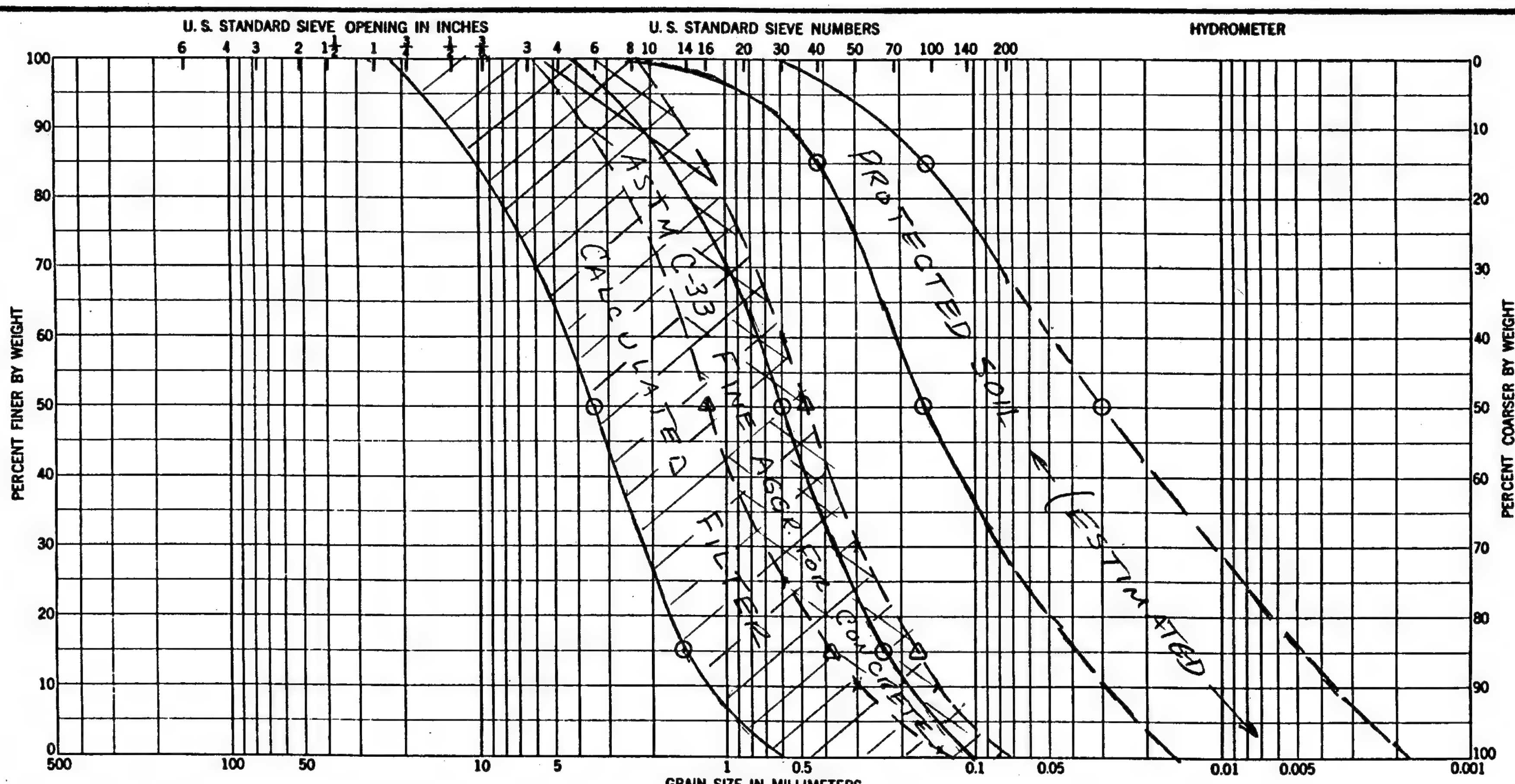
Min $\frac{D_{15FM}}{D_{15PS}} = \frac{0.17}{0.0005} = 34 > 5$

SLOT SIZE

$\frac{D_{50FM(AVE)}}{\text{SLOT WIDTH}} = \frac{0.9}{0.5} = 1.8 > 1.2$

0.5 mm is equivalent to a #20 SLOT = 0.020"

MRO Form 1550, 1 DEC 83



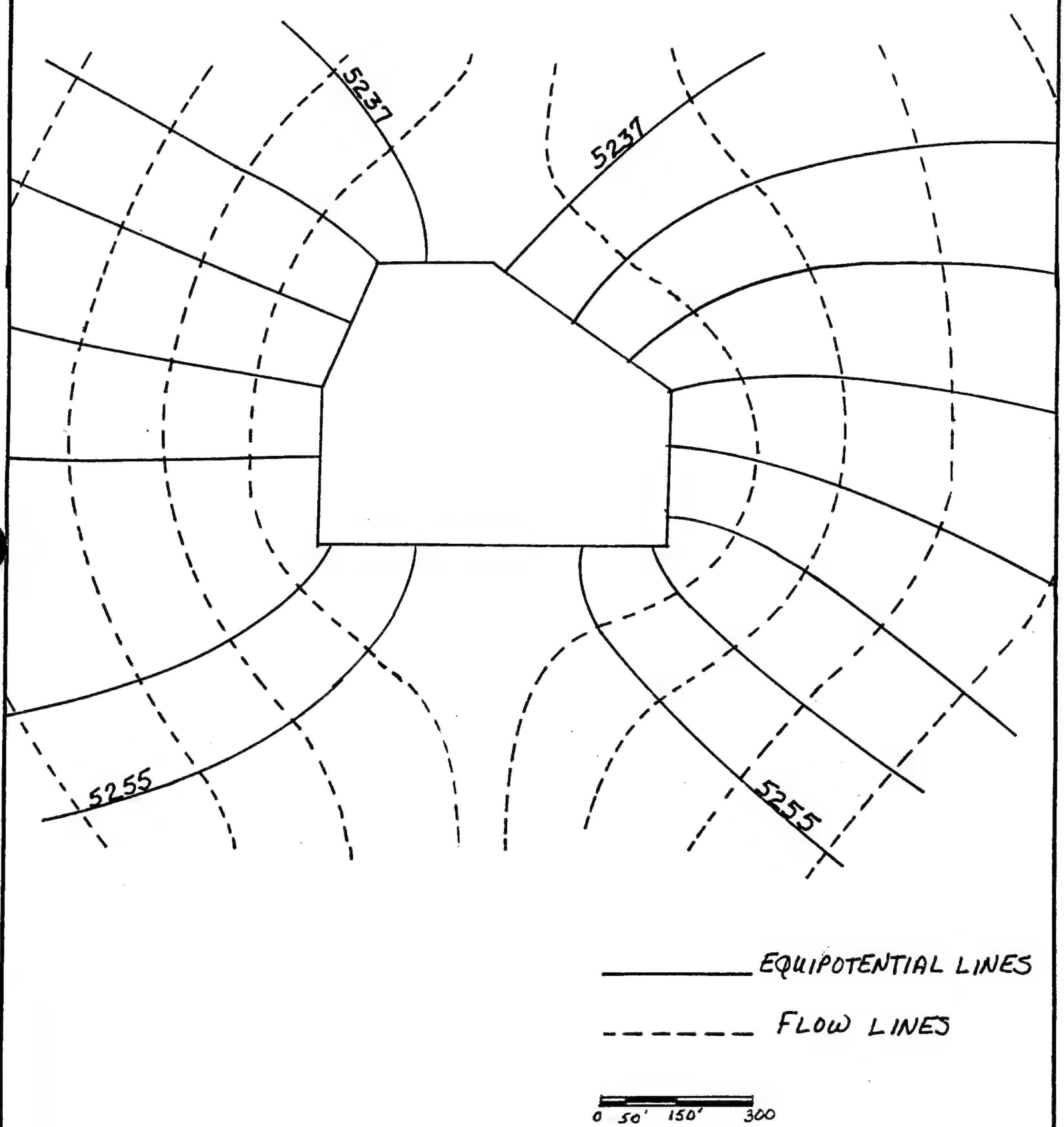
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
LSB 34	15.0'	SANDY LEAN CLAY		31	17	14
LSB 34	20.0'	SILTY SAND		NP	NP	NP
LSB 34	25.0'	SANDY LEAN CLAY		46	19	27
LSB 35	14.0'	SILTY SAND		NP	NP	NP
LSB 35	19.0'	SILTY SAND		NP	NP	NP

Project ROCKY MTN ARSENAL
LIME SETTLING BASINS
Area Ground-Water Extraction Trench
Boring No. LSB 34 & LSB 35
Date 26 SEPT 1990 JZ

GRADATION CURVES

ENG FORM 1 MAY 63 2087.

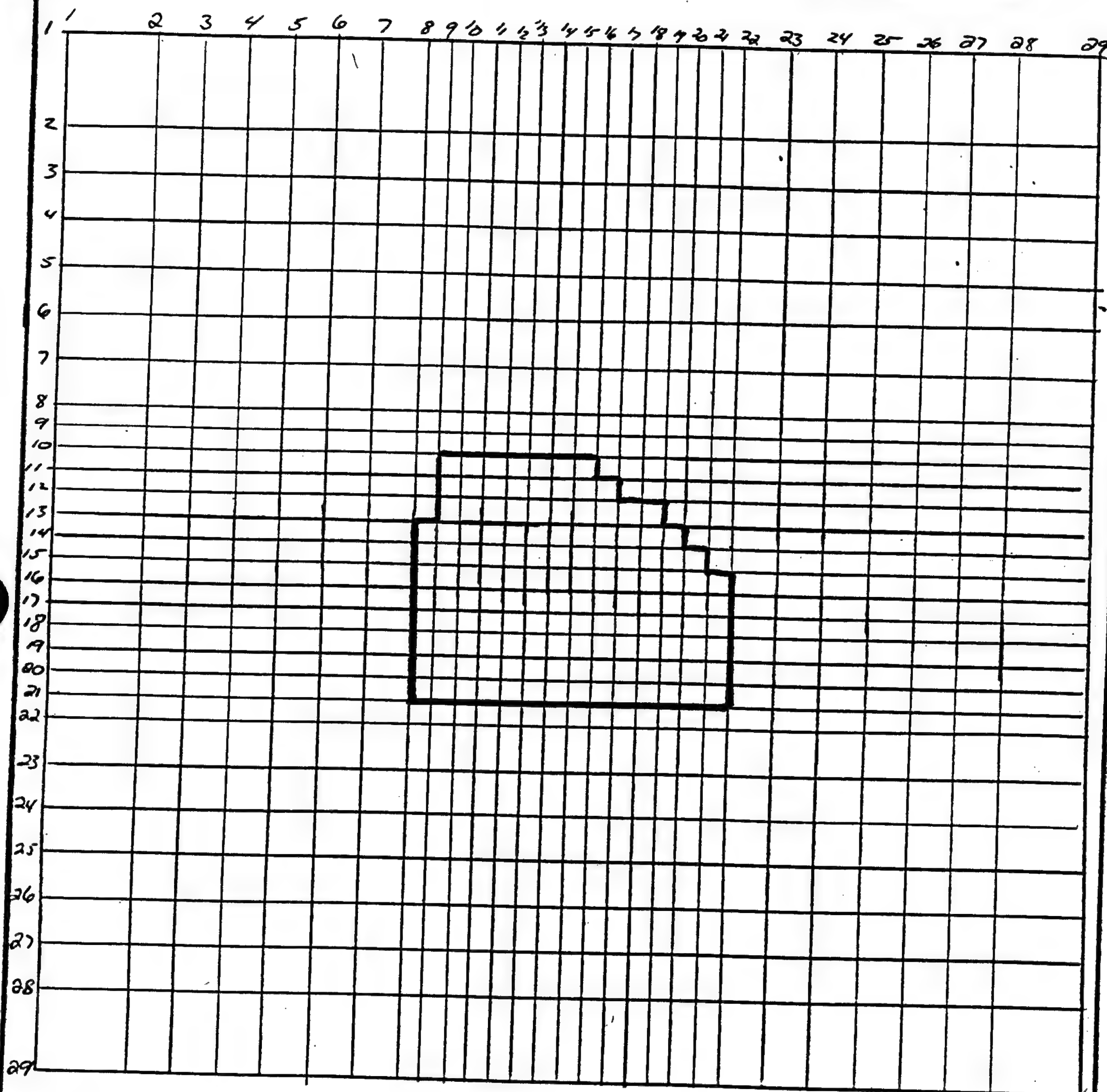
OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - LIME SETTLING BASINS		SHEET NO. 1	OF 1
ITEM Flow DIAGRAM AFTER ISOLATION CELL		BY JMC	DATE 8-10-90
		CHKD. BY	DATE



MRO Form 1550, 1 DEC 83

OMAHA DISTRICT | COMPUTATION SHEET | CORPS OF ENGINEERS

PROJECT RMA Lime Settling basin (LSB)	SHEET NO. 1 OF 2
ITEM Finite difference Grid for LSB Regional flow Model	BY John HArtley · DATE 9-10-90
	CHKD. BY · DATE



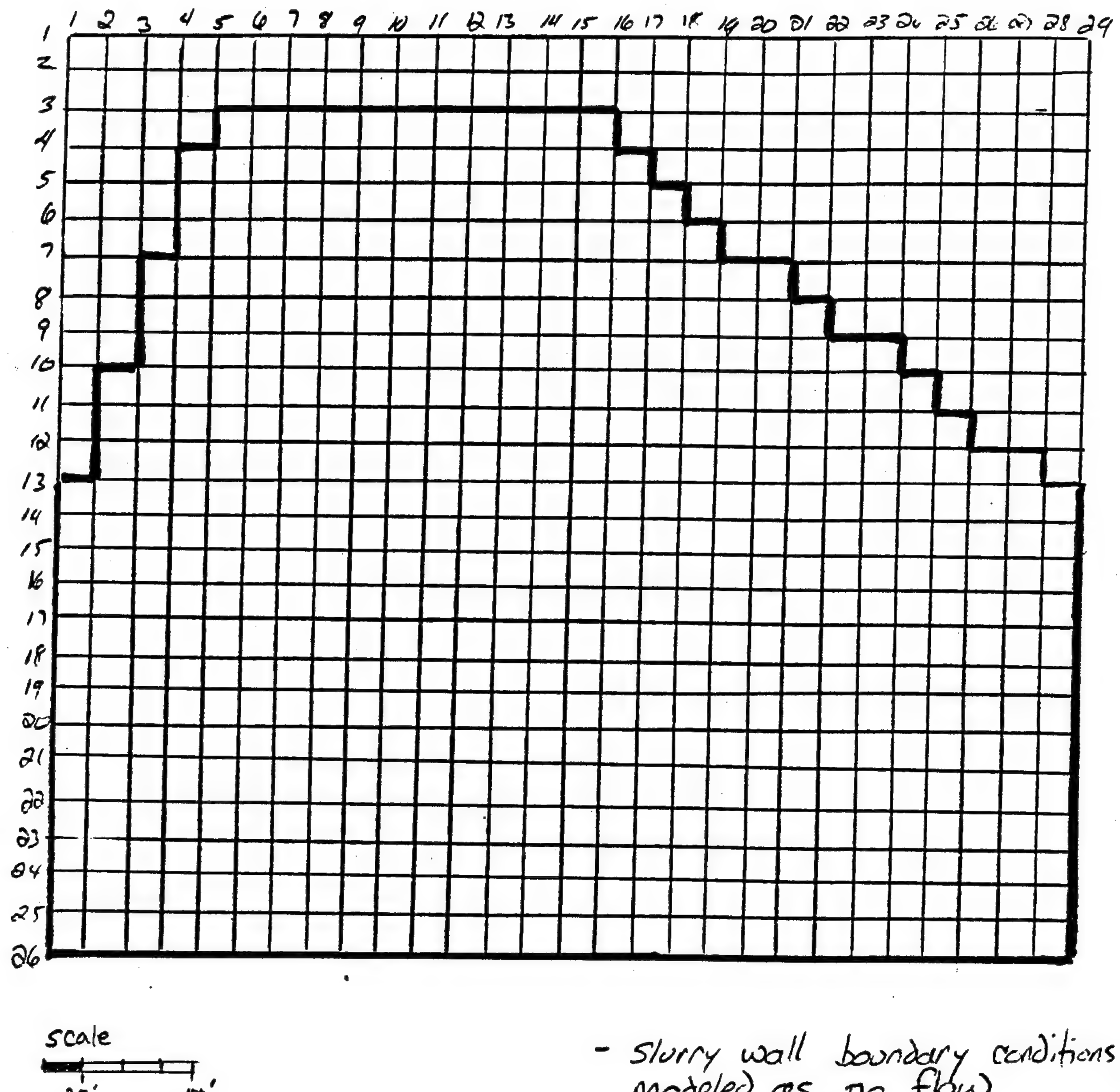
scale
0 100' 200'

- Bold line designates Location of slurry wall

All boundaries modeled using constant head conditions

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT RMA Lime Settling Basin	SHEET NO. 2 OF 2	
ITEM	BY John H Hetley	DATE 10-11-90
Finite Difference Grid Slurry wall system	CHKD. BY	DATE



- Slurry wall boundary conditions modeled as no flow

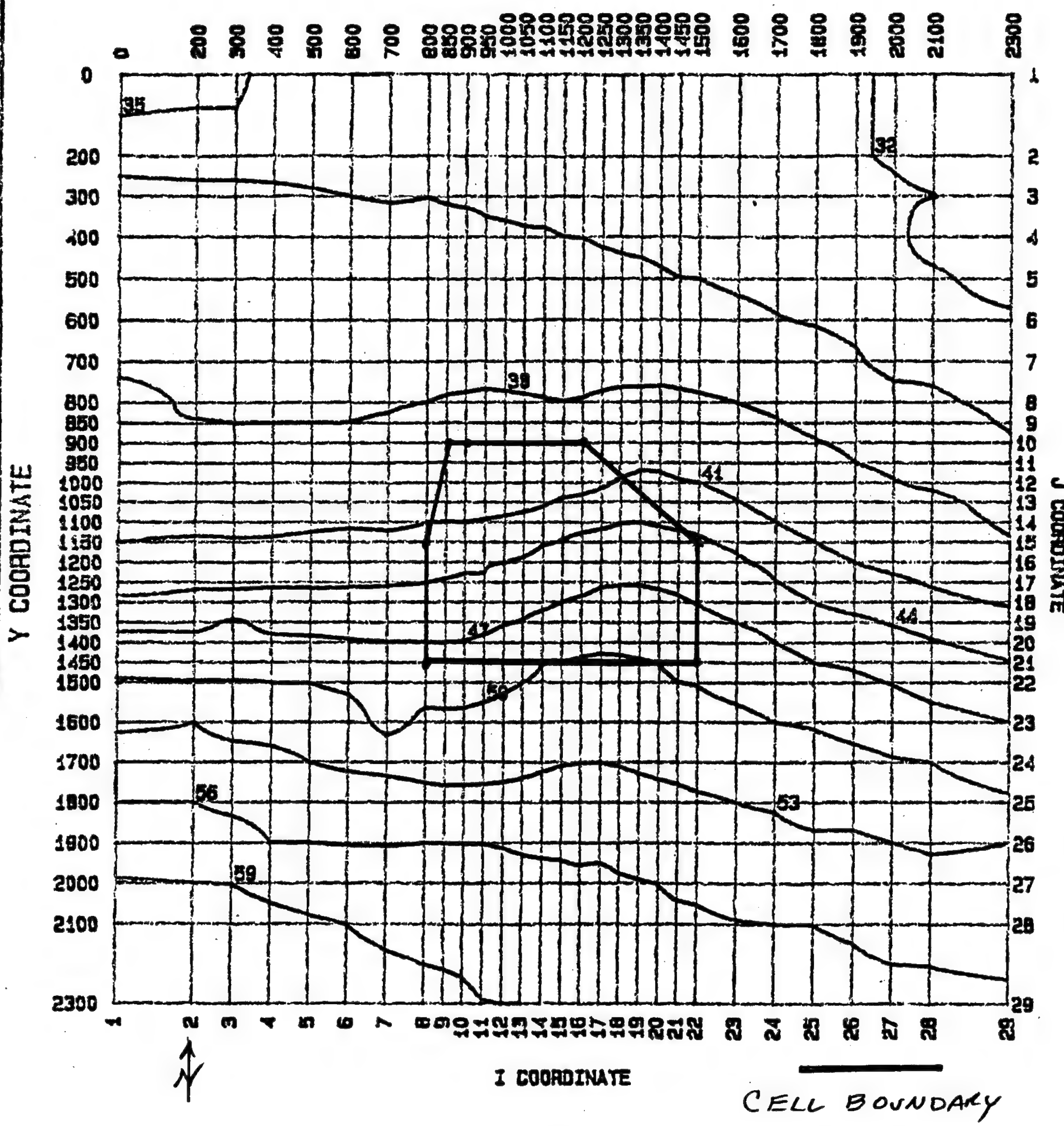
Bold line designates boundary of slurry wall

- north model boundary modeled as constant head

MRO Form 1550, 1 DEC 83

INTERPOLATED CONTOURS

X COORDINATE DISTANCE (FT)



BASE EL 5200

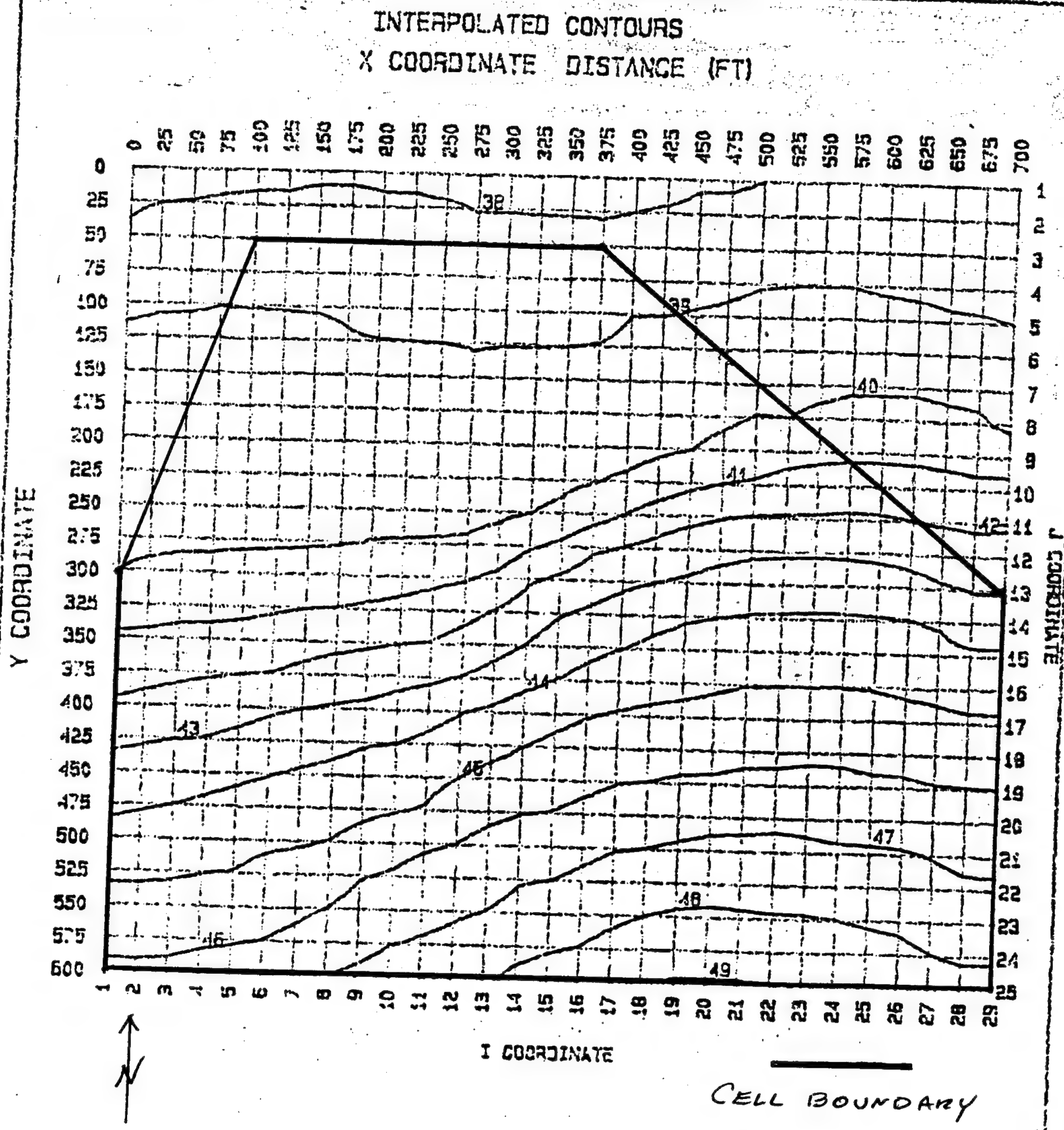
CALIBRATION

PROJECT: RMA
FILE: 1
LOCATION: DENVER

HEAD CONTOURS
AFTER 5 DAYS OF SIMULATION

U.S. ARMY CORPS. ENGINEERS

FIGURE 7

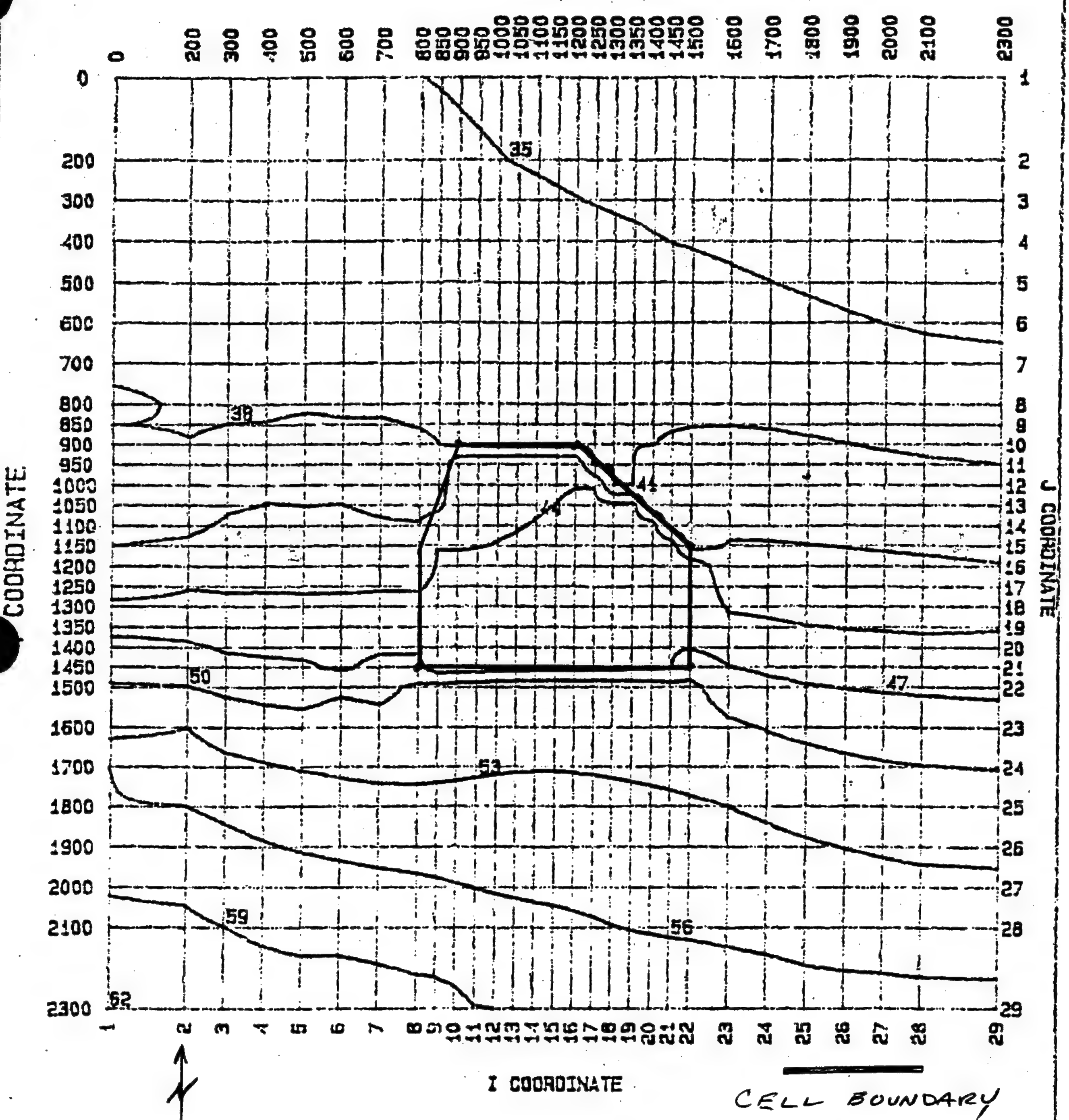


BASE EL 5200

CALIBRATION

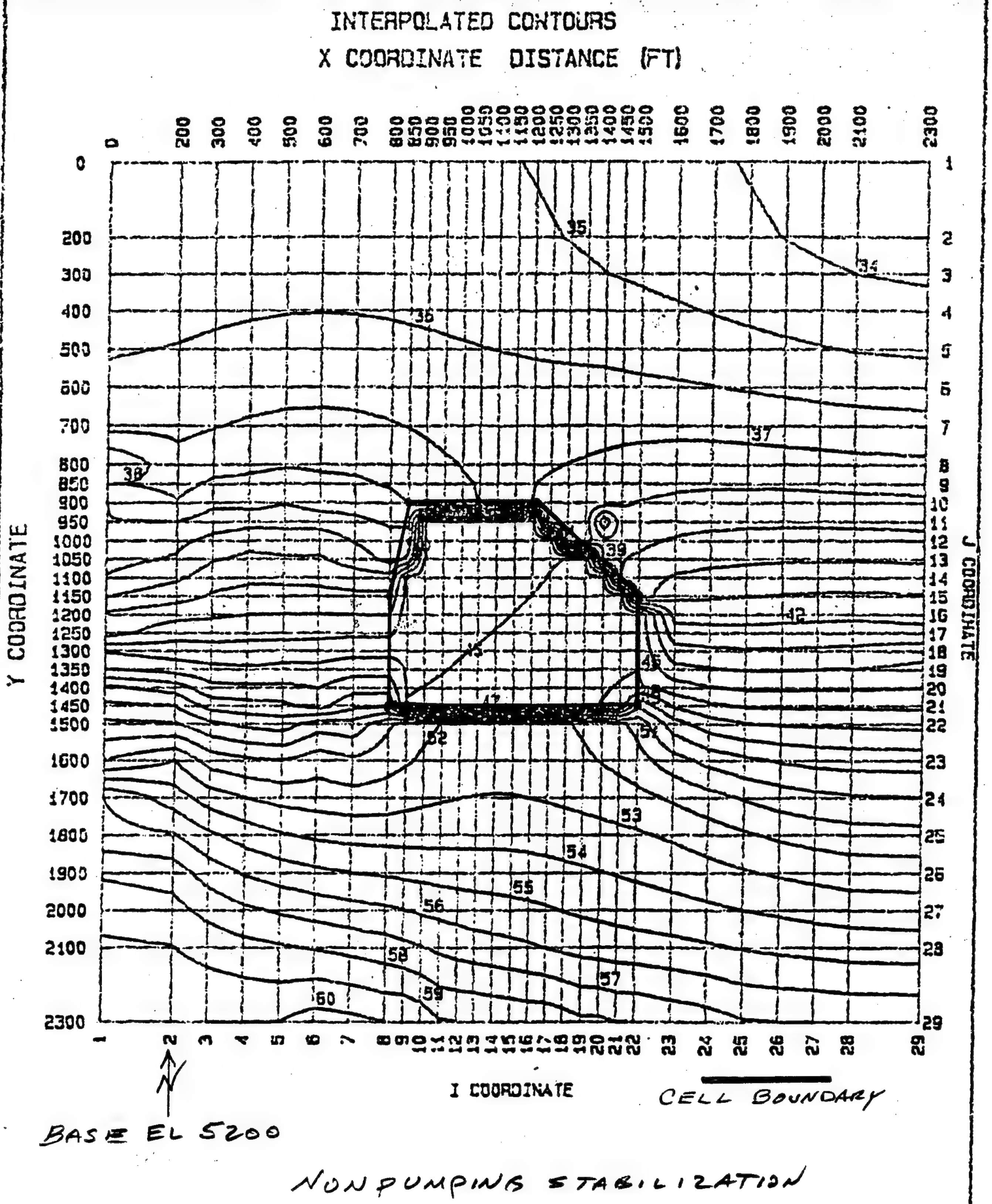
PROJECT: AMA CELL FILE: C1 LOCATION: DENVER	HEAD CONTOURS AFTER 5 DAYS OF SIMULATION
U.S. ARMY CORPS. ENGINEERS	FIGURE 1

INTERPOLATED CONTOURS
X COORDINATE DISTANCE (FT)



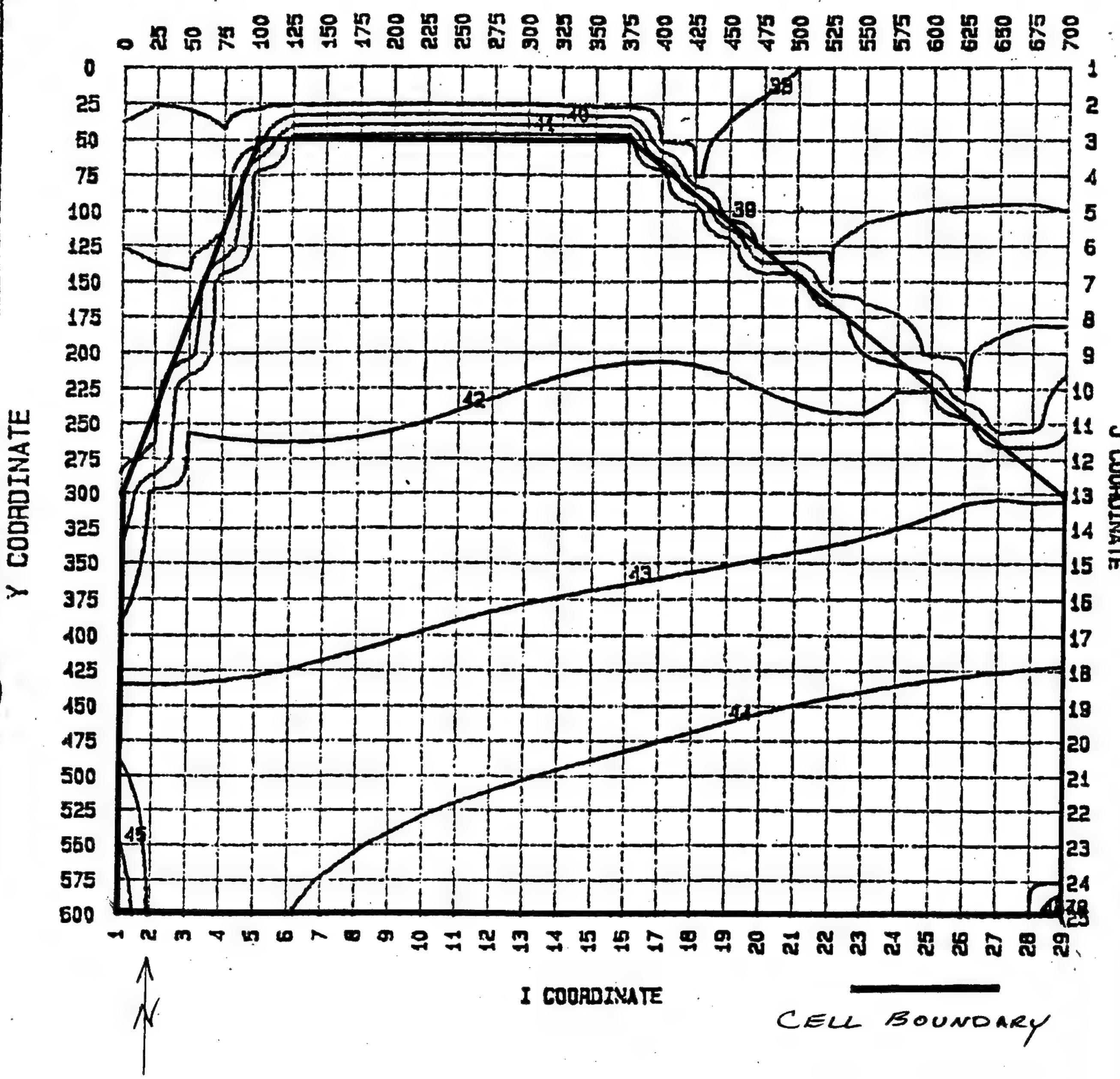
BASE EL 5200 NONPUMPING EQUALIZATION

PROJECT: rma FILE: 1 LOCATION: denver	HEAD CONTOURS AFTER 2359.907 DAYS OF SIMULATION ~ 6½ YEARS
U.S. ARMY CORPS. ENGINEERS	FIGURE 3



PROJECT: RMA "REGIONAL" FILE: 1 LOCATION: DENVER	HEAD CONTOURS AFTER 4096.12 DAYS OF SIMULATION ~ 11 1/4 YEARS
U.S. ARMY CORPS. ENGINEERS	FIGURE 7

INTERPOLATED CONTOURS
X COORDINATE DISTANCE (FT)



BASE EL. 5200

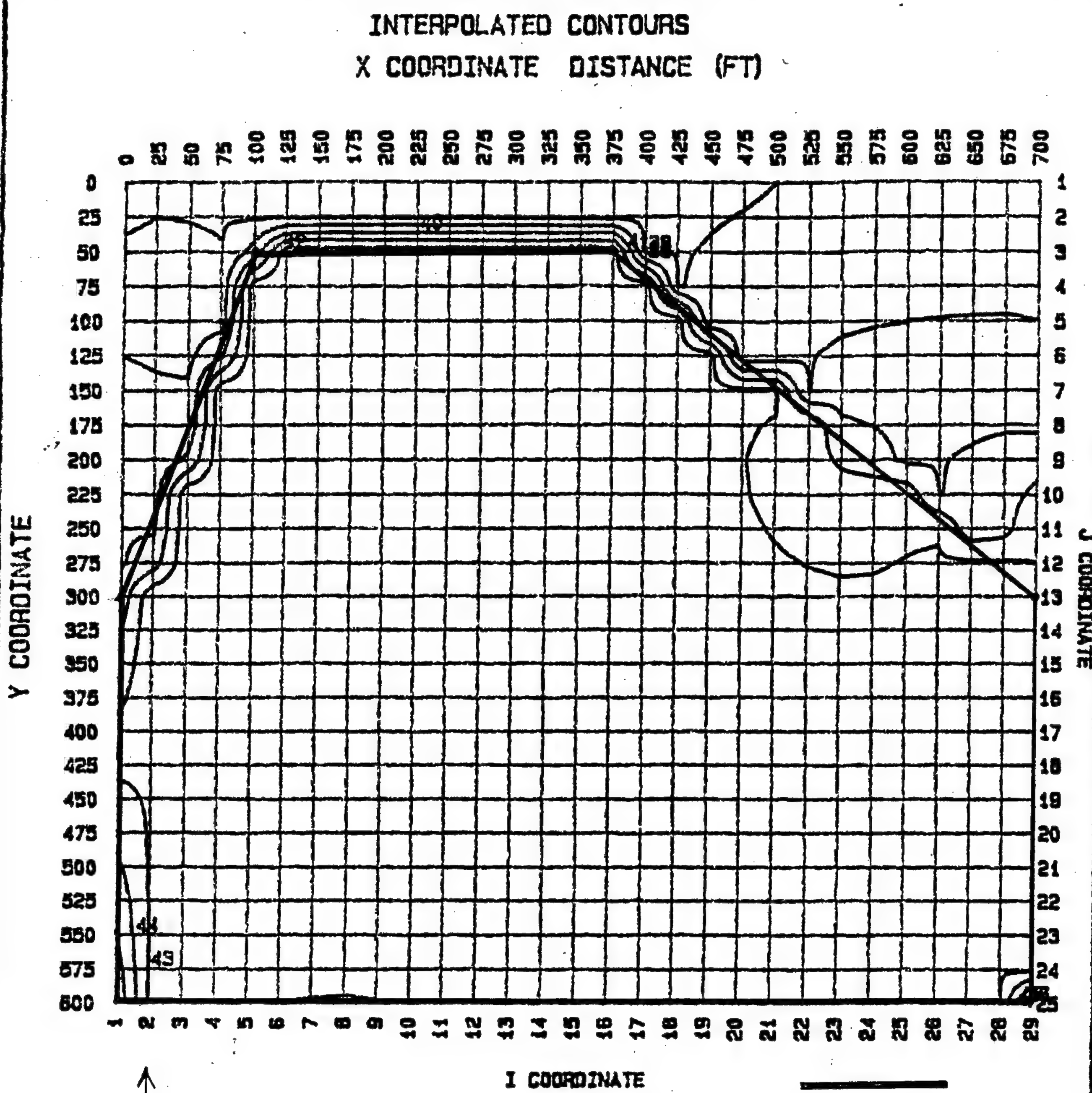
NONPUMPING EQUALIZATION

PROJECT: RMA CELL
FILE: C1
LOCATION: DENVER

HEAD CONTOURS
AFTER 2359.907 DAYS OF SIMULATION
~ 6½ YEARS

U.S. ARMY CORPS. ENGINEERS

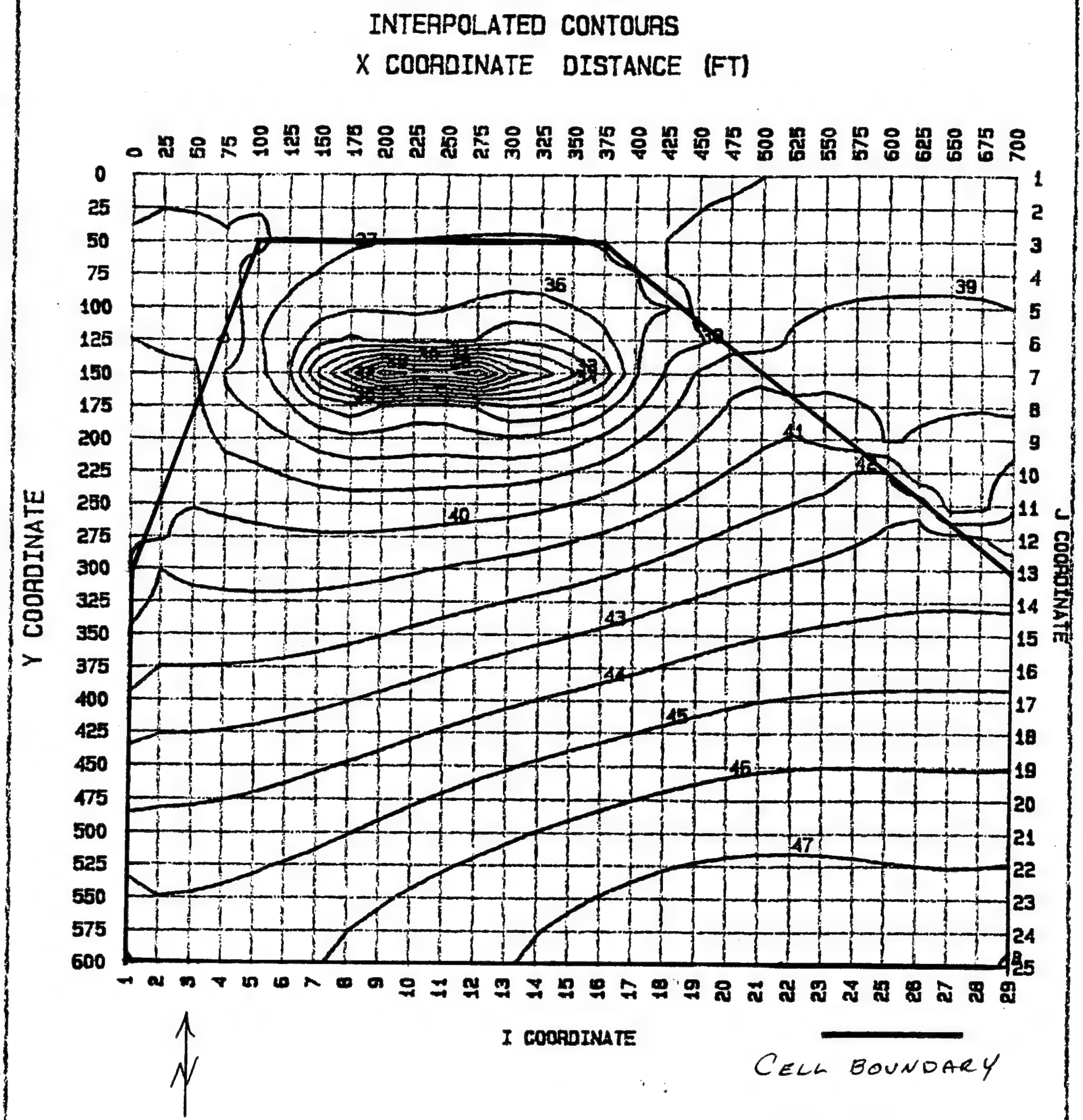
FIGURE 2



BASE EL 5200

NONPUMPING STABILIZATION

PROJECT: RMA CELL FILE: C1 LOCATION: DENVER	HEAD CONTOURS AFTER 7096.295 DAYS OF SIMULATION ~ 19½ YEARS
U.S. ARMY CORPS. ENGINEERS	FIGURE 5



BASE EL. 5200

DRAIN SIMULATION
10 PUMPING WELLS
0.10 GPM EACH = 1.0 GPM TOTAL

PROJECT: RMA CELL
FILE: C1
LOCATION: DENVER

HEAD CONTOURS
AFTER 295.9797 DAYS OF SIMULATION

U.S. ARMY CORPS. ENGINEERS

FIGURE 5

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - Lime Settling Basins		SHEET NO. 1	OF 3
ITEM Ground Water Flow thru Bedrock (Denver Fm)		BY JMC	DATE 5-24-90
		CHKD. BY	DATE

Data obtained from boring log for monitoring well 36109

DEPTH TO A SAND → 61.6 ft.

THICKNESS OF OVERBURDEN → -27.1 ft.

THICKNESS OF CLAYSTONE → 34.5 ft.

GRADIENT OF CLAYSTONE:

5243 ft. Elevation of top of A Sand (head)

-5234 ft. Elevation of head to be maintained in cell

9 ft.

$\frac{9\text{ ft.}}{34.5\text{ ft.}}$ = .26 = Hydraulic Gradient of Claystone

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - Lime Settling Basins		SHEET NO. 2	OF 3
ITEM Ground Water Flow Thru Bedrock		BY JMC	DATE 5-24-90
		CHKD. BY	DATE

Conservative K value for bedrock = 10^{-7} cm/sec

conversion to ft/day:

$$10^{-7}\frac{cm}{sec} = .0000001\frac{cm}{sec} \times 2835\frac{ft}{day} = .0002835\frac{ft}{day}$$

volume of flow:

gradient x K x surface area:

$$.26 \times .0002835\frac{ft}{day} \times 338{,}250 ft^2 = 24.93\frac{ft^3}{day}$$

Assumptions:

K value = 10^{-9} cm/sec = .000000001

conversion to ft^3/day:

$$.000000001\frac{cm}{sec} \times 2835\frac{ft}{day} \times .26 \times 338{,}250 ft^2 = .25\frac{ft^3}{day}$$

K value = 10^{-8} cm/sec = .00000001

conversion to ft^3/day:

$$.00000001\frac{cm}{sec} \times 2835\frac{ft}{day} \times .26 \times 338{,}250 ft^2 = 2.49\frac{ft^3}{day}$$

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA - Lime Settling Basins		SHEET NO. 3	OF 3
ITEM Total GroundWater Flow thru slurry wall AND bedrock		BY JMC	DATE 5-24-90
		CHKD. BY	DATE

$Q_{Tot} = 14.93 \frac{ft^3}{day}$ = total GW flow thru isolation cell (see previous calculations)

$Q = 24.93 \frac{ft^3}{day}$ = total GW flow thru bedrock when $K = 10^{-7} \frac{cm}{sec}$

$$\begin{array}{r} 14.93\ ft^3/day \\ +\ 24.93\ ft^3/day \\ \hline 39.86\ ft^3/day \end{array}$$

$\sim 40\ ft^3/day$ = conservative/maximum estimate of total groundwater flow

---

$Q_{ToT} = 14.93\ ft^3/day$ = total GW flow thru isolation cell

$Q = 2.49\ ft^3/day$ = total GW flow thru bedrock when $K = 10^{-8} \frac{cm}{sec}$

$$\begin{array}{r} 14.93\ ft^3/day \\ +\ 2.49\ ft^3/day \\ \hline 17.42\ ft^3/day \end{array}$$

$\sim 17\ ft^3/day$ = estimated total of groundwater flow

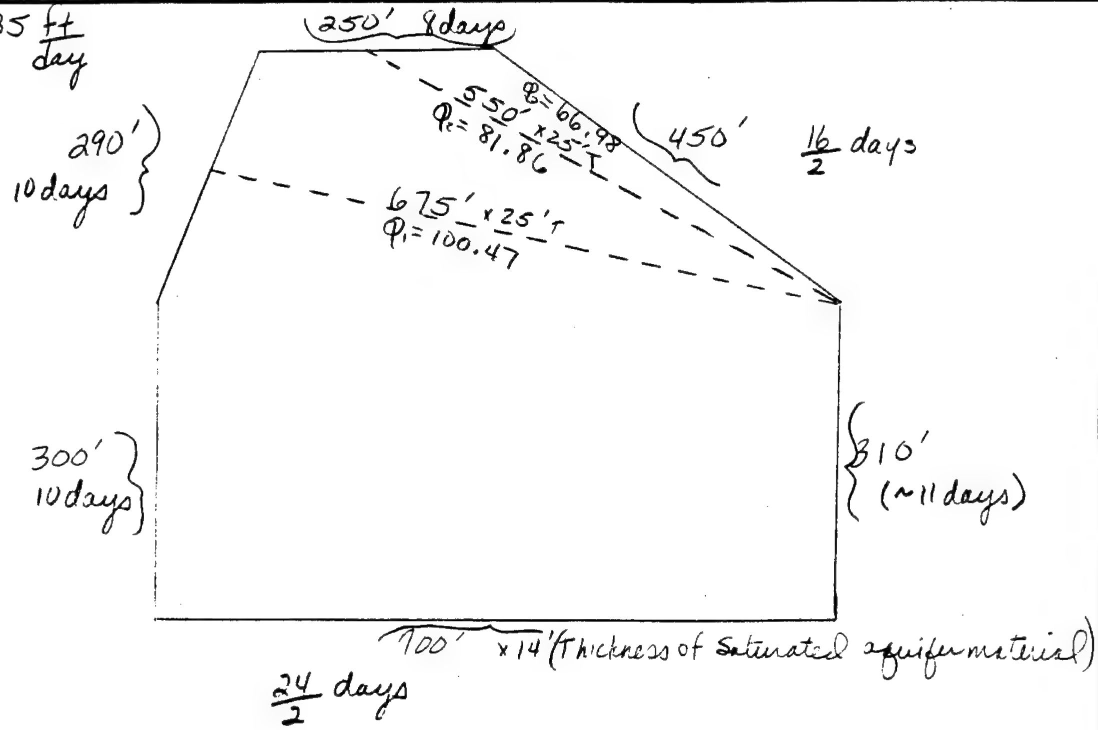
ESTIMATES OF GROUNDWATER FLOW RANGE FROM ~17 to 40 $\frac{ft^3}{day}$

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT RMA Lime Settling Basins		SHEET NO. 1	OF 4
ITEM flow during sequential construction		BY JMC	DATE 20 July 90
		CHKD. BY	DATE

K= $10^{-4} \frac{cm}{sec} = .2835 \frac{ft}{day}$

I= 0.021



$Q = KIA$

$$Q_1 = 0.2835 \frac{ft}{day} \times 0.021 \times (675' \times 25') = 100.47 \frac{ft^3}{day}$$

$$\underset{\text{(S, W, + NW walls)}}{32 \text{ days}} \times Q \left(100.47 \frac{ft^3}{day}\right) = 3215.04 \ ft^3$$

$$Q_2 = 0.2835 \frac{ft}{day} \times 0.021 \times (550' \times 25') = 81.86 \frac{ft^3}{day}$$

$$\underset{\text{(N wall)}}{8 \text{ days}} \times 81.86 \ ft = 654.88 \ ft^3$$

$$Q_3 = 0.2835 \times 0.021 \times (450' \times 25') = 66.98 \frac{ft^3}{day}$$
(NE wall)

$$8 \text{ days} \times 66.98 \frac{ft^3}{day} = 535.84 \ ft^3$$

Total Days = 48 days (+ East Wall (11 day)) = 59 days

Total $Q_t = Q_1 + Q_2 + Q_3 = 4405.76 \ ft^3$

($\sim 4406 \ ft^3$)

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT	SHEET NO. 2 OF 4	
ITEM	BY JMC	DATE 20 July 90
	CHKD. BY	DATE

East Wall - no significant Q

South Wall - $700' \div 30'$ 23.3 days $\div 2 = 11.67$

$.2835 \frac{ft}{day} \times .021 \times (700' \times 14') ft^2 = 58.34 \frac{ft^3}{day}$

11.67 days $\times 58.34 \frac{ft^3}{day} = 680.83 \; ft^3/day/day$

(12 days $\times 58.34 = 700.08 \; ft^3/day$)

West Wall - $300' \div 30' = 10$ days

$.2835 \times .021 \times (300 \times 25) = 44.65 \; ft^3/day$

10 days $\times 44.65 \; ft^3/days = 446.51$

North West Wall $290' \div 30 = 9.67$ days

$.2835 \times .021 \times (290' \times 25') = 43.16 \; ft^3/day$

9.67 days $\times 43.16 = 417.39$

10 days $\times 43.16 = 431.60$

North Wall $250' \div 30' = 8.33 \div 2 = 4.17$ days

$.2835 \times .021 \times (250' \times 25') = 37.21$

4.17 days $\times 37.21 \; ft^3/day = 155.16$

4 days $\times 37.21 = 148.84$

North East Wall $450' \div 30 = 15 \div 2 = 7.5$ days

$.2835 \times .021 \times (450' \times 25') = 66.98$

$7.5 \times 66.98 = 502.33$

$8 \times 66.98 = 535.84$

midpoint from NW Wall   675 ft ÷ 30 ft/day = 22.5 days

Q = .2835 x .021 x (675 x 25) = 100.47

(SW + NW vary by days)

22.5 days x 100.47 = 2260.47

23 x 100.47 = 2310.81

midpoint from N wall   550 ft ÷ 30 ft/day = 18.3 ÷ 2 = 9.17

.2835 x .021 x (550 x 25) = 81.86

9.17 x 81.86 = 750.66

9 x 81.86 = 736.74

OMAHA DISTRICT	COMPUTATION SHEET		CORPS OF ENGINEERS
PROJECT		SHEET NO. 4	OF 4
ITEM		BY JMC	DATE 20 July 90
		CHKD. BY	DATE

Sequential Construction

Days

East Wall	11
South Wall	12
West Wall	10
Northwest Wall	10
North Wall	4
Northeast Wall	8
midpoint from NW Wall	23
midpoint from N wall	9
	87 days

Q

East Wall	~0
South Wall	100.08
West Wall	446.51
Northwest Wall	431.60
North Wall	148.84
Northeast Wall	535.84
midpoint from NW wall	2310.81
midpoint from N Wall	736.74

$Q_t = 5310.43\ ft^3$

Total Q during construction

TABLE 1
SOIL-BENTONITE SLURRY TRENCH QUALITY CONTROL TESTING

Subject	Test: Standard	Test: Specific Test	Test: Frequency
Bentonite Powder	API STD-13A	a. YP/PV Ratio b. Plastic Viscosity c. Filtrate d. Record: d1. Wet Screen Analysis d2. Moisture Content	1 per truck shipment (100 bags)
Chemical Analysis of Water	API RP 13B-1	a. pH b. Hardness c. Total Dissolved Solids d. Oil, Organics etc.	Initially and monthly thereafter
	ASTM D152	Chloride	1 per water supply source or if changes occur
Initial Soil Bentonite Slurry Properties	API RP 13B-1	a. Viscosity b. Density c. pH	3 per shift (see Note 1)
In-Trench Soil Bentonite Slurry Properties	API RP 13B-1	a. Viscosity b. Density c. Sand Content	3 per shift (see Note 1)
Backfill Material	ASTM D 422 ASTM D 4318	Grain Size Atterberg limits	1 per 500 cubic yds
Soil-Bentonite Backfill Material	ASTM C 143 API RP 13B-1	Slump Cone Density	3 per shift (see Note 1)
	ASTM D 422	Grain Size	1 per 2000 cubic yds
	ASTM D 2216 EM 1110-2-1906	Moisture Permeability	1 per 100 ft. length or per new batch (see Note 2)
Compacted Clay	ASTM D 422	Grain Size	1 per 2000 cubic yds
	ASTM D 2922 ASTM D 3017	Density (Nuclear) Moisture (Nuclear)	5 per lift 5 per lift

Notes:

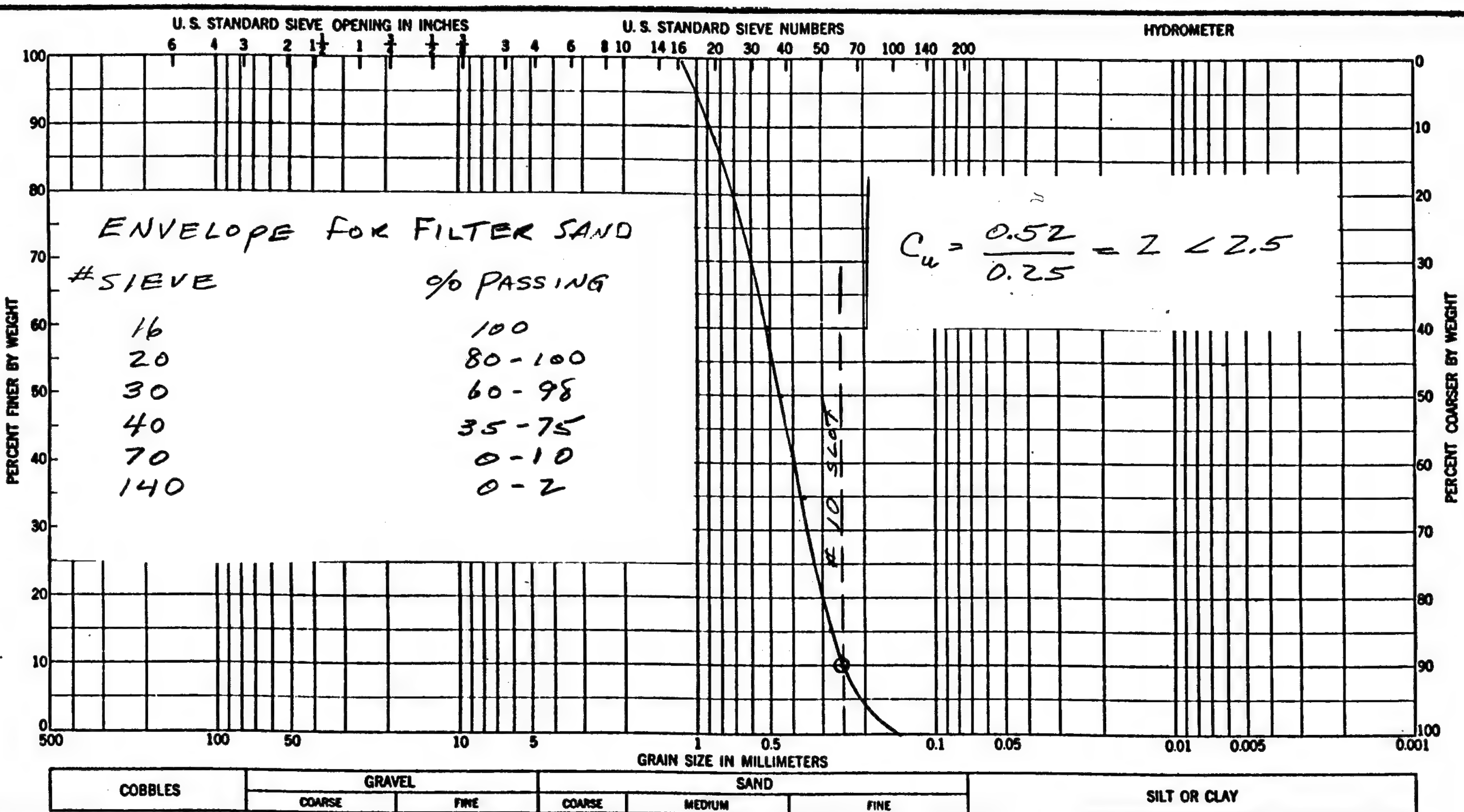
1) If more than one (1) batching plant is being used, these frequencies shall apply to each batching plant separately.
2) Permeability test may be performed using fixed wall permeameter except that for every five such tests, there shall be performed one test using flexible wall permeameter.
3) Requirements of permeability on completed soil-bentonite cutoff wall are specified in Subparagraph: Slurry Trench.

TABLE 2
SOIL-BENTONITE SLURRY TRECH QUALITY ASSURANCE TESTING

Subject	Test: Standard	Test: Specific Test	Test: Frequency
Initial Soil Bentonite Slurry Properties	API RP 13B-1	a. Viscosity b. Density c. pH	1 per 3 shifts (Note 1)
In-Trench Soil Bentonite Slurry Properties	API RP 13B-1	a. Viscosity b. Density c. Sand Content	1 per 3 shifts (Note 1)
Backfill Material	ASTM D 422 ASTM D 4318	Grain Size Atterberg limits	1 per 5000 cubic yds
Soil-Bentonite Backfill Material	ASTM C 143 API RP 13B-1	Slump Cone Density	1 per 3 shifts (Note 1)
	ASTM D 422	Grain Size	1 per 10000 cubic yds
	ASTM D 2216 EM 1110-2-1906	Moisture Permeability	1 per 500 ft. length or per new batch (Note 2)

Notes:

1) If more than one (1) batching plant is being used, these frequencies shall apply to each batching plant separately.
2) Permeability test may be performed using fixed wall permeameter except that for every five such tests, there shall be performed one test using flexible wall permeameter.
3) Requirements of permeability on completed soil-bentonite cutoff wall are specified in Subparagraph: Slurry Trench.



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
		SILTY SAND, CLAYEY SAND				
		SANDY CLAY				
FILTER	DESIGN BA	SED ON #10 SLOT SCREEN				
WITH U	NIFORMITY	COEFFICIENT ≤ 2.5				

Project ROCKY MTN ARSENAL
LIME SETTLING BASINS
Area MONITOR WELLS & PIEZOMETERS
Boring No. GENERAL
Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087

****
****

VEGETATIVE COVER FOR LIME SETTLING BASINS
ROCKY MOUNTAIN ARSENAL, COLORADO
OCTOBER 12, 1990

****
****

POOR GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	6.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.1053 VOL/VOL
WILTING POINT	=	0.0466 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0815 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.003060000017 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.3394 VOL/VOL
FIELD CAPACITY	=	0.0906 VOL/VOL
WILTING POINT	=	0.0466 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0771 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000085000000 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	73.68
TOTAL AREA OF COVER	=	385000. SQ FT
EVAPORATIVE ZONE DEPTH	=	14.00 INCHES
UPPER LIMIT VEG. STORAGE	=	5.3372 INCHES
INITIAL VEG. STORAGE	=	0.9741 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

DEFAULT RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR DENVER COLORADO

MAXIMUM LEAF AREA INDEX = 1.00
START OF GROWING SEASON (JULIAN DATE) = 128
END OF GROWING SEASON (JULIAN DATE) = 284

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.50	33.60	38.00	47.40	57.20	67.00
73.30	71.40	62.60	51.90	38.70	32.60

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 74 THROUGH 76

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.48	0.58	1.28	1.56	1.40	1.58
	2.48	1.55	1.03	0.97	1.09	0.31
STD. DEVIATIONS	0.47	0.23	0.08	0.62	1.37	0.83
	0.26	1.23	0.82	0.69	0.78	0.16
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.589	0.561	1.116	1.512	1.378	1.971
	2.442	1.788	0.850	0.931	0.863	0.353
STD. DEVIATIONS	0.431	0.316	0.231	0.503	0.811	0.967
	0.161	1.131	0.584	0.720	0.478	0.142
PERCOLATION FROM LAYER 2						
TOTALS	0.0009	0.0008	0.0008	0.0008	0.0008	0.0009
	0.0012	0.0012	0.0011	0.0011	0.0010	0.0010
STD. DEVIATIONS	0.0005	0.0005	0.0005	0.0005	0.0005	0.0003
	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 74 THROUGH 76

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	14.32	(1.079)	459327.	100.00
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	14.353	(0.604)	460508.	100.26
PERCOLATION FROM LAYER 2	0.0115	(0.0018)	369.	0.08
CHANGE IN WATER STORAGE	-0.048	(0.550)	-1551.	-0.34

****

****

PEAK DAILY VALUES FOR YEARS 74 THROUGH 76

	(INCHES)	(CU. FT.)
PRECIPITATION	1.79	57429.2
RUNOFF	0.000	0.0
PERCOLATION FROM LAYER 2	0.0001	1.7
SNOW WATER	0.47	15079.2

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1686

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0463

****

****

FINAL WATER STORAGE AT END OF YEAR 76

LAYER	(INCHES)	(VOL/VOL)
1	0.42	0.0695
2	0.85	0.0710
SNOW WATER	0.00	

****
****

CONVERSATION RECORD

TIME	DATE
10:00 am	6 FEB. 1990

TYPE ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
MARK ZAPPI	CEWES-EE-S	(601) 634-2854

SUBJECT
SLURRY WALL COMPATIBILITY TESTING, ROCKY MOUNTAIN ARSENAL

SUMMARY
OUR BASIC PLAN FOR SLURRY WALL COMPATIBILITY TESTING IS OK BUT NEEDS SOME FINE TUNEING. HE RECOMMENDED USING MOSTLY FLEXIBLE WALL PERMEAMETERS BUT A FEW REPLICATE SAMPLES IN RIGID WALL SINCE FLEXIBLE WALLS DON'T SHOW SAMPLE SHRINKAGE. HE ALSO SUGGESTED RUNNING EACH SAMPLE IN TRIPLICATE. MARK SAID RUN AT LEAST ONE PORE VOLUME OF TAP WATER THROUGH THE SAMPLES FOLLOWED BY AT LEAST 2 PORE VOLUMES OF CONTAMINATED GROUND WATER. HE AGREED CALCIUM IN THE SOILS (LIME SETTLING BASINS) COULD EXCHANGE WITH SODIUM IN BENTONITE TO INCREASE PERMEABILITY AND SUGGESTED ~~RUNNING~~ TRACKING SODIUM AND CALCIUM INTO AND OUT OF THE SYSTEM. HE SUGGESTED USING WES LAB TO RUN THE TESTS IF MRD LAB COULD NOT DO TESTING. MARK SAID TRYING TO DETERMINE CONTAMINANT BREAKTHROUGH TIME IS A GOOD IDEA BUT NOT PRACTICAL WITH PERMEAMETERS.

ACTION REQUIRED
UPDATE SCOPE OF SERVICES INCORPORATING ABOVE INFORMATION. LOOK FURTHER INTO USING WES LAB FOR TESTING.

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
JANE M. BOLTON	Jane M. Bolton	6 FEB. 1990

ACTION TAKEN
SCOPE UPDATED. MRD LAB, NOT WES, WILL DO TESTING

SIGNATURE	TITLE	DATE
Jane M. Bolton	CIVIL ENGINEER	20 FEB. 1990

CONVERSATION RECORD

TIME: 12:45
DATE: 9/5/90

TYPE

☐ VISIT ☐ CONFERENCE ☒ TELEPHONE
☒ INCOMING
☐ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
DR. WAYNE CHARLIE P. E.	COLORADO STATE UNIV.	(303) 491-8584

SUBJECT

ROCKY MTN. ARSENAL - M-1 BASINS
SHEET PILE DESIGN

SUMMARY

DR. CHARLIE WAS INFORMED THAT WE WERE DESIGNING A SHEET PILE WALL AT RMA TO PREVENT MIGRATION OF GROUNDWATER INTO THE AREA TO BE VITRIFIED, AND WE NEEDED INFORMATION ABOUT WHAT TYPE OF SHEET PILE TO SPECIFY BASED ON BLOW COUNTS DURING EXPLORATORY DRILLING. HE SAID THERE IS INFO. IN THE NAVY DESIGN MANUAL 7.2 EARTH & EARTH RETAINING STRUCTURES. HE ALSO HAS SOME INFO. THAT HE WILL FAX ME. HE SAID THE BLOW COUNTS USING 3" DIAMETER SPLIT SPOONS ~~INSTEAD OF 2" DIAM.~~ WOULD BE HIGHER THAN WITH SPT 2" SPLIT SPOONS. I ALSO EXPRESSED CONCERNS ABOUT VIBRATIONS CAUSING PROBLEMS WITH ADJACENT STRUCTURES LEFT IN PLACE (>20 FT. AWAY). HE SAID AN ASCE ARTICLE ABOUT CONSTRUCTION VIBRATIONS PASSED OUT IN HIS SOIL DYNAMICS CLASS WOULD HAVE INFO., BUT THAT PROBABLY IF PEAK VIBRATIONS WERE BELOW 1 OR 2 INCHES/SEC. THINGS WOULD BE O.K. HE ALSO RECOMMENDED USING A VIBRATORY HAMMER INSTEAD OF A DRIVING HAMMER AND

ACTION REQUIRED

LOCATE REFERENCES AND USE IN DESIGN.

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
JANE BOLTON	Jane Bolton	9/5/90

ACTION TAKEN

REFERENCES LOCATED. VIBRATORY HAMMER AND SETTLEMENT MONUMENTS PUT IN PLANS & SPECS. SIZING OF PILE GIVEN TO CEMRO-ED-DF

SIGNATURE	TITLE	DATE
Jane Bolton	CIVIL ENGINEER	9/25/90

CONVERSATION RECORD

TIME	DATE

TYPE ☐ VISIT ☐ CONFERENCE ☐ TELEPHONE ☐ INCOMING ☐ OUTGOING

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:

ROUTING	
NAME/SYMBOL	INT

SUBJECT

SUMMARY

CONT.

MAYBE PUTTING A FEW SETTLEMENT MARKERS NEAR SOME STRUCTURES AND MONITORING THEM ONCE A DAY AT THE BEGINNING OF DRIVING TO SEE IF THERE ARE ANY PROBLEMS.

(DR. CHARLIE IS AN ASSOCIATE PROFESSOR CIVIL ENGINEERING AT CSU SPECIALIZING IN SOIL DYNAMICS AND FOUNDATIONS. HE WAS MY GRADUATE PROGRAM ADVISOR)

ACTION REQUIRED

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE

ACTION TAKEN

SIGNATURE	TITLE	DATE

CONVERSATION RECORD

TIME	DATE
8:30 PM	10/2/90

TYPE ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☐ INCOMING ☒ OUTGOING

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
MIKE SNEIDER		(301) 962-4772

ROUTING

NAME/SYMBOL	INT

SUBJECT
SLURRY TRENCH "SET-UP" TIME

SUMMARY
MR. SNEIDER WAS INFORMED OF MY QUESTIONS AND CONCERNS ABOUT THE NUMBER OF DAYS FOLLOWING SLURRY WALL BACKFILL INSTALLATION BEFORE HEAVY EQUIPMENT CAN CROSS THE WALL WITHOUT DAMAGE. HE SAID ON KANE AND LOMBARD THE SOIL-BENTONITE BACKFILL DID A LOT OF HARDENING WITHIN 2-3 DAYS AFTER INSTALLATION. HE RECOMMENDED PLACING THE CLAY COVER ABOUT 2-3 DAYS AFTER BACKFILLING. WHEN ASKED ABOUT HEAVY EQUIPMENT CROSSING THE WALL HE RECOMMENDED AT LEAST 3' OF COMPACTED CLAY AT THE CROSSING LOCATION.

ACTION REQUIRED
INCORPORATE INFO. INTO PLANS & SPECS

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
JANE BOLTON	Jane Bolton	10/2/90

ACTION TAKEN
INFO. INCORPORATED

SIGNATURE	TITLE	DATE
Jane Bolton	CIVIL ENGINEER	10/3/90

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-001

BORING LOCATION: Sec. 36		ELEVATION AND DATUM	
DRILLING AGENCY: Layne Western	DRILLER: K. Cross	DATE STARTED / DATE FINISHED: 7-9-90	
DRILLING EQUIPMENT: CME75		COMPLETION DEPTH: 32	SAMPLER: T. Terry
DRILLING METHOD: Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST.	UNDIST.
SIZE AND TYPE OF CASING: NA		WATER ELEV.: FIRST 10	COMPL. / 24 HRS.
TYPE OF PERFORATION: NA	FROM TO FT.	LOGGED BY: T. Terry	CHECKED BY: ~~PID PPM~~
SIZE AND TYPE OF PACK: NA	FROM TO FT.		
TYPE OF SEAL: Grout	FROM 0 TO 35 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 In)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–6	Fill, sand, grayish white chunks and crystals, moist, appears to be lime, brown, light gray, dark brown							4 4 5 / 7 12 12	
6–14	Sand, very moist to wet, loose, light brownish gray, 10YR5/2 (SP) silty							2 2 4 / 3 2 5	0 PPM

PROJECT NO. 89 MC 114 A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-001

DEPTH (FEET)	DESCRIPTION	Penetr. Resist. (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14			
15		5	24.9
		7	
16	Sand, very silty, grayish brown, wet, medium dense, iron oxide staining (SM) 10YR6/2	8	
17			
18			
19			
20		4	
		6	
21	Clay, trace sand and silt, wet, brown, stiff to very stiff (CL) 10YR5/3	11	
22			
23			
24			
25		4	
		6	
26		7	
27			
28			
29			
30		6	
		10	
31		38	
32	CORE		

DRAFT

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-001

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (ft)	Penetra. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32–35	Claystone, silty, firm to hard fractured, ironoxide staining (CH) 10YR 5/3, 10YR 4/2 DENVER FORMATION					CORE			

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-002

BORING LOCATION	Sec. 36	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-9-90
DRILLING EQUIPMENT	CME 75	COMPLETION DEPTH 32.5	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV. FIRST 10	COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 32.5 FT	

DEPTH (FEET)	DESCRIPTION	Penetr. Resist. (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–8.5	Fill, Sand, lime, moist, white, brown, trace gravel, 10YR8/1, 10YR4/3	11, 11, 13	ND
		8, 7, 5	ND
		3, 3, 3	
8.5–12	Sand, little silt, very moist, wet, loose, dark grayish brown, (SP) 10YR4/2	2, 2, 3	ND
12–14	Sand, silty, wet, medium dense to dense, yellowish brown, (SM), 10YR5/4		

Graphic Log columns: Lithology, Piezometer Installation, Water Content, Piezometer Data; Samples: Type No., Recovery, Penetr. Resist.

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-002

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (ft)	SAMPLES: Penetr. Resist (Blows 6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								7	37.2
								8	
16								10	
17	Clay (Weathered Claystone) very stiff, pale brown, yellowish brown, fractured, blocky, (CL) 10YR 6/3, 10YR 5/4								
20								8	85.4
								11	
21								15	
25								5	1.4
								11	
26								13	
27	Claystone, siltstone, hard to very hard, yellowish brown, iron oxide staining, (CH), 10YR 5/4								
30								13	11.9
								23	
31								30	4.7
32						CORE			

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-3

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER M. WALKER	DATE STARTED / DATE FINISHED 7-10-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" HSA		COMPLETION DEPTH 37.5	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow stem augers	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 13	COMPL. 15 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. MORRISSETTE	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL GROUT	FROM 0 TO 37.5 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) gravelly silty SAND, very fine grained, poorly graded, medium dense, dry, 10YR 4/3 brown to dark brown				Topsoil
1	(SM) silty SAND, fine-grained, poorly graded, medium dense, dry, 10YR 4/3 brown to dark brown				
2					
3		SS	16	9 8 6	PID=ND
4					
5		SS	9	12 10 9	PID=2.0ppm
6	becomes slightly clayey				
7	becomes 10YR 6/4 light yellowish brown				
8		SS	16	5 5 5	PID=ND
9					
10	(SC) clayey SAND, fine-grained, poorly graded, medium dense, very moist, 10YR 6/4 light yellowish brown	SS	17	6 5 5	Alluvium PID=3.0ppm
11					
12					
13	(SM) silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR 5/4 yellowish-brown				water enters ATD Alluvium
14					

PROJECT NO. 89MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-3

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (")	SAMPLES: Penetr. Resist. (Blows/6 in.)	REMARKS (Drill Rate, Field Tests, Odor, etc.)
14	SAME: (SM) silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR5/4 yellowish-brown								Alluvium
15						SS	14	7 12 13	PID = 29 ppm
16									
17									
18									
19									
20						SS	17	6 9 11	PID = 15 ppm
21	(CL) sandy silty CLAY, low to medium plastic, stiff to very stiff, very moist, 10YR5/3 brown to 10YR7/3 very pale brown								Alluvium reworked shale bedrock
22									
23									
24									
25	(CH) silty clay SHALE, highly plastic, firm, very moist, 10YR2/2 very dark brown, iron oxide stains, carbonaceous					SS	15	9 12 17	Denver Fm. slightly weathered PID = 17 ppm
26									
27									drilling becomes stiffer
28	becoming unweathered								
29	Claystone					CORE			Core run #1
30									
31									
32									

XGur 11Lha

SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME DOE D.O. 1 HOLE NO. LSB-3

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	(CH) silty clay ~~SHALE~~, highly plastic, medium hard, very moist, 10YR 2/2 very dark brown, iron oxide stains, carbonaceous claystone					CORE			Denver Fm unweathered
33									
34									Bottom of boring at 33.5 feet
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									

DRAFT

PROJECT NO. 84MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-4

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-9-90	
DRILLING EQUIPMENT CME 750 w/6-5/8" OD HSA		COMPLETION DEPTH 29.0	SAMPLER 2" OD split spoon
DRILLING METHOD Hollow stem augers	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 7.0	COMPL. ND / 24 HRS.
TYPE OF PERFORATION —	FROM TO FT.	LOGGED BY S. Morrissette	CHECKED BY
SIZE AND TYPE OF PACK —	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 29.0 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SC) clayey silty SAND, fine-grained, poorly graded, very stiff, moist, 10YR5/3 brown, organic, with roots				Topsoil
1	(SM) silty SAND, fine-grained, poorly-graded, subangular to subrounded, dense, moist, 10YR5/4 yellowish-brown				Alluvium
2				14	
3		SS	14	21, 15	PID=ND
4					
5		SS	15	4, 4, 4	PID=ND
6					
7	becomes 10YR6/3 and wet				water enters ATD
8		SS	17	6, 6, 6	PID=ND
9					
10		SS	18	3, 4, 4	PID=ND-8ppm
11					
12					
13					
14					

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME Coe D.O. 1 HOLE NO. LSB-4

Depth (feet)	Description	Lithology	Piezometer Installation	Water Content	Piezometer Data	Samples: Type No.	Recov. (")	Penetr. Resist. (Blows/6 in)	Remarks (Drill Rate, Fluid loss, Odor, etc)
14–16	SAME: silty SAND (SM), fine-grained, poorly graded, subangular to subrounded, dense, wet, 10YR6/3					SS	18	9 11 13	Alluvium; PID=ND
16–17.5	(CL) sandy silty CLAY, low plastic, very stiff, fine grained sand, wet, 10YR5/3 brown with 10YR8/2 white mottling								Alluvium reworked shale
17.5–23	(CH) sandy silty CLAY, highly plastic, medium hard, very moist, 10YR6/4 light yellowish-brown. Weathered Claystone					SS	17	10 15 24	Denver Fm weathered; PID=ND
23–29	(CH) silty CLAY SHALE, highly plastic, hard, very moist, 10YR6/4 light yellowish-brown to 10YR3/1 dark gray, slightly carbonaceous					SS; CORE	18; 1.8'	13 20 25	Denver Fm unweathered; PID=ND; Core run #1
29									Bottom of boring at 29.0 feet

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-5

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-9-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" OD HSA		COMPLETION DEPTH 36.5	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow stem augers	DRILL BIT	NO. OF SAMPLES DIST. 8	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 4.5	COMPL. ND 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. Morrissette	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 36.5 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov. ft	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine-grained, poorly graded, subangular to subrounded, medium dense, dry, 10YR5/4 yellowish-brown				aeolian sand/silt or fill (?)
3	becomes moist	SS	16	6 5 4	PID=ND
5		SS	18	5 5 4	PID=ND
6	(SM ~~to ML~~) silty SAND ~~to sandy silt~~, fine-grained, poorly-graded, medium dense, moist, 10YR5/2 grayish-brown				Alluvium
7	(SM) silty SAND, fine-grained, poorly-graded, subangular to subrounded, medium dense, moist, 10YR5/4 yellowish-brown				Alluvium
8		SS	14	5 6 3	PID=ND
9.5					water enters ATD
10		SS	14	5 18 28	PID=ND

DRAFT

PROJECT NO. 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-5

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. ft	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: (SM) silty SAND, fine-grained, poorly-graded, subangular to subrounded, medium dense, moist, 10YR5/4 yellowish-brown								Alluvium
15						SS	18	7 8 9	PID=ND
16	~~(ML) slightly sandy SILT~~, non-plastic, medium dense, very fine grained sand, wet, 10YR5/3 brown Silty Sand								alluvium
18	(SM) slightly clayey silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR4/4 dark yellowish-brown								Alluvium
20						SS	18	5 7 10	PID=ND Alluvium reworked shale
21	(CL) sandy silty CLAY, low plastic, stiff, fine-grained SAND, very moist, 10YR8/2 white to 10YR8/3 very pale brown								
23	(CH) Sandy silty CLAY, highly plastic, hard, fine-grained sand, blocky 10YR5/3 brown, carbonaceous Weathered Claystone								Denver Fm weathered
25						SS	14	12 24 32	PID=ND
26	(CH) slightly sandy silty CLAY, highly plastic, very hard, moist, 10YR5/3 brown, iron oxide stains Claystone								Denver Fm unweathered
30						SS	18	27 41 65	PID=19ppm
31						CORE			Core Run #1
32									

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-5

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: (CH) slightly sandy silty clay, highly plastic, very hard, moist, 10YR5/3 brown, iron oxide stains					CORE			Denver Fm unweathered
33									
34									
35									
36									
37									Bottom of boring at 36.5 FT.
38									
39									
40									
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									

8GMC114A

SHEET 3 OF 3

DRAFT

Woodward-Clyde Consultants PROJECT NAME Coe D.O. 1 HOLE NO. LSB-9

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 6-20-90 / 6-21-90	
DRILLING EQUIPMENT CME 55 with 6-5/8" OD HSA		COMPLETION DEPTH 47.5	SAMPLER 3.0 OD SS
DRILLING METHOD Hollow stem augers	DRILL BIT	NO. OF SAMPLES: DIST. 10	UNDIST. 2
SIZE AND TYPE OF CASING —		WATER ELEV.: FIRST 8.5	COMPL. 22 / 24 HRS.
TYPE OF PERFORATION —	FROM — TO — FT.	LOGGED BY S. Morrissette	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO — FT.		
TYPE OF SEAL — Grout	FROM 0 TO 47.5 FT.		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) Silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR 4/4 dark yellowish-brown, *	SM							Aeolian sand & silt
3						SS	16	7 7 9	PID=ND
5	becomes siltier and more moist					SS	18	4 6 7	PID=ND
7	(ML) ~~Sandy SILT~~, non-plastic, soft, very moist, 10YR 4/4 dark yellowish-brown	ML							Alluvium
8	becomes wet					SS	16	1 1 1	PID=ND; water enters ATD
9	silty sand (SM)								
10.5						SS	15	5 11 12	PID=ND
11	(SM) Silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR 5/4 yellowish-brown	SM							Alluvium

PROJECT NO. 89MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-9

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (")	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR5/4 yellowish-brown	SM							Alluvium
15						SS	13	2 9 16	PID=ND
16	with some siltier zones								
17									
18									
19									
20						SS	18	4 9 11	PID=ND
21	with some thin seams (1/2") of SILT, 10YR 8/3 very pale brown								
22									← WATER 17 HRS AD
23									
24									
25						SS	11"	11 50/5	PID=ND Alluvium
26	silty CLAY, highly plastic, hard, wet, 10YR3/1 very dark gray, with trace of coarse grained gravel	CH							Alluvium
27	silty SAND, fine-grained, poorly graded, very dense, wet, 10YR4/6 dk. yellowish brown with some 2.5YR5/4 mottling	SM							
28									
29									
30						SS	4	50/4	PID=ND
31									
32									

SHEET 2 OF 3

PROJECT NO. 89MC114A

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-5

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov.	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: silty SAND, fine-grained, poorly graded, very dense, wet, 10YR 4/6 with some 2.5YR 5/4 mottling	SM							Alluvium
33									
34									
35						SS	4	50/4	PID=ND
36									
37									
38	~~SHALE~~: silty CLAY, highly plastic, hard, very moist, 10YR 4/2 dark grayish-brown with some iron-oxide staining, carbonaceous	CH							Denver Fmn
39									
40	Claystone					SS	9"	36 50/3	PID=ND
41									core run #1
42						CC #1	8 5		
43									
44									
45									Core run #2
46						CC #2	30 5		
47									
48									Bottom of boring at 47.5 feet
49									
50									

DRAFT

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. LSB-10

BORING LOCATION Lime Settling Basins.		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER R. Parker	DATE STARTED / DATE FINISHED 6-21-90 / 6-22-90	
DRILLING EQUIPMENT CME 55 with 6-5/8" OD HSA		COMPLETION DEPTH 47.5	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow Stem augers	DRILL BIT	NO. OF SAMPLES DIST. 9	UNDIST. 2
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 10.5	COMPL. 25.5 (24 hrs.)
TYPE OF PERFORATION —	FROM — TO — FT.	LOGGED BY S. McRrissette	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO — FT.		
TYPE OF SEAL — Grout	FROM 0 — TO 47.5 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recovery	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	~~(SM)~~ silty SAND, fine grained, poorly graded, medium dense, dry, 10YR5/6 yellowish-brown. Fill								aeolian sand & silt / Fill(?)
2	(CL) sandy silty CLAY, low to medium plastic, stiff, very moist, 10YR6/1 gray to light gray with trace of medium gravel and some wood chips. Fill								Fill/Sludge
3						SS		4, 9, 10	PID=ND
5	(CL) silty CLAY, low to medium plastic, medium stiff, very moist ~~10YR~~ 2.5YR 6/N6 gray. Fill								Sludge
6						SS	6	2, 3, 4	PID=ND
7	(SM) silty SAND, very fine grained, poorly graded, medium dense, very moist, 10YR 4/2 dark grayish-brown or sandy SILT								Alluvium/Eolian sand/silt
8						SS		3, 5, 6	PID=ND
10	(SM) silty SAND, very fine grained, poorly graded, loose, wet, 10YR5/2 grayish brown								Alluvium
11						SS		1, 2, 3	← water enters ATD; PID=ND

PROJECT NO. 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. CSB-10

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist. Bl/6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(SM) SAME: silty SAND, very fine grained, poorly graded, loose, wet, 10YR5/2 grayish brown								Alluvium
15						SS	9	6 7 13	PID=ND
16									
17									
18									
19									
20	becomes less silty					SS	0	5 11 14	PID=3.0ppm
21									
22									
23	(SM) ~~sandy SILT~~, nonplastic, wet, 10YR4/2 dark grayish-brown or silty SAND silty Sand								Alluvium
24									
25						SS	[illegible]	5 11 15	PID=1.2ppm
26									
27									
28	(SM) silty SAND, very fine grained, poorly graded, medium dense, wet, 10YR4/3 brown to dark brown								Alluvium
29									
30						SS	9	17 50/5	PID=ND
31									
32									

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-10

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov.	Penetr. Resist. Blows/6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	(SM) SAME: Silty SAND, very fine-grained, poorly graded, medium dense, wet, 10YR 4/3 brown to dark brown								alluvium
33	(CL to CH) ~~silty CLAY SHALE~~: silty CLAY, WEATHERED medium to highly plastic, hard, very moist, 10YR 5/4 yellowish-brown with trace of fine grained SAND, blocky texture Claystone								Denver Fm
35						SS	0	33 50/1	PID = ND stopped drilling 6-21-90
36									resumed drilling 6-22-90
37	(CH) WEATHERED ~~SHALE~~: silty CLAY, highly plastic, hard, very moist, 10YR 6/1 light gray to gray with iron oxide staining and iron nodules Claystone								~~weat~~ Denver fm
40									core run #1
41						CC #1			
42	WEATHERED SANDSTONE: silty SAND, fine-grained, poorly graded, wet, 10YR 7/1 light gray with iron oxide staining and iron nodules								Denver fm
43	(CH) WEATHERED ~~SHALE~~: silty CLAY, highly plastic, hard, very moist, 10YR 6/1 light gray to gray with iron oxide staining and iron nodules claystone								Denver fm
44									core run #2 Denver fm
45	(CH) ~~SHALE~~: silty CLAY, medium to highly plastic, hard, very moist, 10YR 4/1 dark gray with trace of fine grained silty SAND seams, 10YR 6/1 light gray Claystone								
46						CC #2			
47									
48									
49									Bottom of boring at 47.5 feet
50									

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-11

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 6-28-90	
DRILLING EQUIPMENT CME 55 with 6-5/8" HSA		COMPLETION DEPTH 29.5	SAMPLER 3" split spoon
DRILLING METHOD HOLLOW STEM AUGERS	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 13	COMPL. 17 24 HRS. 5 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. MORRISSETTE	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL — GROUT	FROM 0 TO 29.0 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(Sm) silty SAND, fine-grained, poorly graded, medium-dense, dry, 10YR 6/6 brownish-yellow				aeolian sand/silt
3		SS	16	9 11 9	PID=ND
5.5	with some 10YR 8/1 white mottling	SS	15	6 15 15	PID=ND
7	(Sm) silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR 5/8 yellowish-brown ~~color changes to 10YR 5/8 yellowish-brown, and becomes very moist~~				Alluvium
8		SS	15	6 6 13	PID=ND
10	with some siltier zones color changes to 10YR 6/8 brownish-yellow, and becomes very moist	SS	16	9 12 10	PID=ND
13					Water enters ATD

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-11

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: (SM) silty SAND, fine-grained, poorly-graded, medium-dense, wet, 10YR6/8 brownish-yellow								Alluvium
15						SS	18	7 12 15	PID=ND
17									water level noted on drill rods as of 1100.
20						SS	10	4 11 13	PID=16 ppm Alluvium ~~Denver Fm~~ (reworked ~~shale~~) Claystone
21	(CL) sandy silty clay ~~SHALE~~, low to medium plastic, very stiff, very moist, 10YR8/2 white to 10YR8/3 very pale brown								
22	Weathered Claystone								
25						SS	12	8 17 16	PID=ND-0.9ppm Denver Fm
26	(CH) silty clay ~~SHALE~~, highly plastic, hard, 10YR5/1 gray with some iron oxide staining Claystone					CORE RC	34"		CORE RUN #1
29									Bottom of boring at 29.5 FEET

DRAFT

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB15

BORING LOCATION: Sec 36		ELEVATION AND DATUM:	
DRILLING AGENCY: Layne Western	DRILLER: R. McKay	DATE STARTED / DATE FINISHED: 6/25/90	
DRILLING EQUIPMENT: CME 75		COMPLETION DEPTH: 38	SAMPLER: T. Terry
DRILLING METHOD: Hollow Stem	DRILL BIT:	NO. OF SAMPLES: DIST.	UNDIST.
SIZE AND TYPE OF CASING: 4 in PVC		WATER ELEV.: FIRST 13 ft	COMPL. / 24 HRS.
TYPE OF PERFORATION: 10 Slot	FROM 18 TO 23 FT.	LOGGED BY: T. Terry	CHECKED BY:
SIZE AND TYPE OF PACK: 10-20 Sand	FROM 13 TO 23 FT.		
TYPE OF SEAL: Bentonite	FROM 11 TO 13 FT		

DEPTH (FEET)	DESCRIPTION	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–1	Gravel, sandy, dry, dense, brown, 10 YR 5/3 (GP)		
1–6	Sand, dry to slightly moist, loose to medium dense, medium to fine sand, brownish yellow 10YR 5/3 to 10YR 4/4 (~~SP~~ SM) silty	5 4 4	ND
		3 4 13	ND
6–	Slightly ~~clayey~~, Sand, medium to fine sand, dense, brownish yellow (SC) 10YR 4/4 silty	8 14 15	ND
			Enviroplug
10	Very moist to wet	4 12 10	ND
			Bentonite
14	(Next page)		

Graphic Log: Lithology, Piezometer Installation; Water Content; Piezometer Date; Samples: Type No., Recov./ft.

PROJECT NO. ~~2050~~ 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB 15

DEPTH (FEET)	DESCRIPTION	Penetration Resist. (Blows/6 in)	REMARKS PID PPM (Drill Rate, Fluid loss, Odor, etc)
14–25	Clay, sandy, medium to fine sand, wet to moist, stiff, Olive to light olive brown, iron oxide staining, layered (CL), ~~10~~ 5Y 5/4, 2.5Y 5/4 clayey Sand	5 9 10 (15)	ND
		3 8 11 (20)	3.0
25–30	Clay, slightly sandy, v. moist to dry, Color varies from very pale brown to dark brown, medium stiff to stiff (CL) 10YR7/4, 10YR4/3	5 7 8	ND
30–32	weathered Claystone, stiff to very stiff, moist to dry, pale olive ~~5Y6/3~~ to olive gray, blocky, crumbly, (LCH) 5Y 6/3, 5Y4/2	6 13 12	ND

Piezometer installation: grout (below ~23 ft)

PROJECT NO. ~~2050~~ 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB 15

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov. (ft)	Penetra. Resist. (Blows 6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
32									
33	Claystone, firm, moist, weak red, gray, black, (CH) 10~~Y~~R 4/2								
34									
35								13 16 18	73
36									
37						CORE			78
38									

PROJECT NO. ~~2050~~ 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-17

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 7-3-90 / 7-5-90	
DRILLING EQUIPMENT CME 75 w/ 6-5/8" HSA		COMPLETION DEPTH 31.5	SAMPLER 3" split spoon
DRILLING METHOD HOLLOW STEM AUGERS	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. /
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 7.0	COMPL. ND 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. MORRISSETTE	
TYPE OF SEAL — GROUT	FROM 0 TO 31.5 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recovery	Penetration Resistance (Blows/6 In)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	~~(SM)~~ silty SAND, fine-grained, poorly graded, dense, moist, 10YR5/3 brown Fill								Fill ~~(?)~~
3						SS	17	9 17 16	PID=ND
6	becomes very moist and loose to very loose					SS	18	2 1 3	PID=ND
7	(SM ~~or ML~~) silty SAND ~~or sandy SILT~~, very loose, fine-grained, poorly graded, very loose, wet, 10YR 5/3 brown,								Alluvium water enters ATD
8	becomes 10YR5/1 gray					SS	16	1 1 1	PID=ND
10	(SM) silty SAND, fine grained, poorly graded, medium dense, wet, 10YR6/2 light brownish-gray								Alluvium
11						SS	17	8 12 16	PID=ND
12									
13									
14									

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-17

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Penetration Data	SAMPLES: Type No.	SAMPLES: Recov.	SAMPLES: Blows	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(SM) silty SAND, fine grained, poorly graded, medium dense, 10YR5/3 brown								Alluvium
15–16.5						SS	18	5 10 15	PID=ND
19	(CL) sandy silty CLAY, low to medium plastic, stiff to very stiff, very moist, 10YR4/4 dark yellowish-brown, fine grained SAND								Alluvium reworked shale
20.5–22						SS	13	5 9 11	PID=3ppm
23	(CH) silty clay ~~SHALE~~, highly plastic, very stiff, very moist, 2.5Y6/4 light yellowish-brown Weathered claystone								Denver Fm: weathered
25.5–26.5						SS	12	7 11 13	PID=34ppm
26.5									CORE RUN #1
27–30						CORE			
28	becoming less weathered								
29	(CH) silty clay ~~SHALE~~, highly plastic, very stiff to hard, very moist, 10YR5/1 gray to 10YR3/1 very dark gray, iron oxide stains, aragonite crystals claystone								Denver Fm.
31.5									Bottom of boring @ 31.5 FT.

PROJECT NO. 89MC114A SHEET 2 of 2

Woodward-Clyde Consultants PROJECT NAME COE D.O.1 HOLE NO. LSB-18

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 7-2-90 / 7-3-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" HSA		COMPLETION DEPTH 39	SAMPLER 3" Splitspoon
DRILLING METHOD HOLLOW STEM AUGERS	DRILL BIT	NO. OF SAMPLES DIST. 8	UNDIST. 2
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 7.0	COMPL. 8.0 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. MORRISSETTE	
TYPE OF SEAL — Grout	FROM 0 TO 39 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov.	Penetr. Resist. Blows/6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	~~(SM)~~ silty SAND, fine-grained, poorly-graded, medium dense, moist, 10YR 6/6 brownish-yellow with trace of 10YR7/1 light gray silty CLAY Fill				Fill
3		SS	15	6 12 15	PID=ND
6	with wood fragments and trace of bright yellow 5Y 8/8 stains, becomes loose	SS	11	3 3 4	PID=ND
7	(SM) silty SAND, fine-grained, poorly-graded, medium-dense, wet, 10YR5/4 yellowish-brown				water enters ATD Alluvium
8		SS	16	3 5 4	water at 8.0 FT as of 0650 7-3-90 PID=ND
10	(SM) slightly silty SAND, fine to medium grained, poorly graded, medium dense, wet, 10YR 5/2 grayish-brown				Alluvium
11		SS	11	2 7 11	PID=ND
12					
13					
14					

PROJECT NO. 89MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-18

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: (SM) silty SAND, fine to medium grained, poorly graded, dense, wet, 10YR5/2 grayish-brown								Alluvium
15						SS	18	11 16 24	PID=627ppm
16	becomes 10YR5/3 brown with 10YR5/1 gray mottling								
17	(ML) ~~SILT~~, ~~non-plastic~~, stiff to very stiff, very moist to wet, 10YR5/3 brown with trace of very fine SAND and iron oxide stains								Alluvium
18	Clay, low plasticity								
19									
20						SS	17	4 10 11	PID=114
21									
22									
23									
24	(CL to SC) sandy silty CLAY to clayey SAND, low to medium plastic, very stiff, very moist, 10YR5/3 brown with 10YR8/1 white mottling								~~Denver Fm~~ Alluvium reworked shale
25						SS	18	4 10 14	PID=8ppm
26									
27									
28	(CH) silty CLAY ~~SHALE~~, hard, highly plastic, very moist, 10YR5/2 grayish-brown with thin fine grained SAND seams, iron oxide stains, and blocky texture, carbonaceous. Weathered Claystone								Denver Fm. WEATHERED
29									
30						SS	14	16 28 34	PID=124ppm
31									
32						CC			Core run #1

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. LSB-18

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	GRAPHIC LOG Piezometer Installation	Water Content	Penetration Data	SAMPLES Type No.	SAMPLES Recov.	SAMPLES Penetr. Resist. Blows/6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: (CH) silty clay ~~SHALE~~, hard, highly plastic, very moist, 10YR5/2 grayish-brown with thin fine-grained SAND seams, iron oxide stains, and blocky texture, carbonaceous								Core run #1 Denver Fm. WEATHERED
33						CC			
34	Weathered Claystone								
35	(CH) silty clay ~~SHALE~~, hard, highly plastic, very moist, 10YR4/2 dark grayish-brown, iron oxide stains, carbonaceous, becomes 10YR 2/2 very dark brown at 36 FEET								Core run #2 Denver Fm
36						CC			Seam of white crystalline material at ~37 FEET
37	becomes 10YR4/1 dark gray Claystone								
38									
39	becomes 10YR6/1 light gray to gray								Bottom of Boring @ 39.0 FEET.
40									
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									

PROJECT NO. 84MC114A SHEET 3 OF 3

RECEIVED
JUL 25 1990

Woodward-Clyde Consultants PROJECT NAME Coe D.O. 1 HOLE NO. LSB-19

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-11-90 / 7-12-90	
DRILLING EQUIPMENT CME 750 w/6-5/8" OD HSA		COMPLETION DEPTH 29.5	SAMPLER 3" split spoon
DRILLING METHOD Hollow stem Augers	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. /
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 10.0	COMPL. 14 / 12 HRS.
TYPE OF PERFORATION —	FROM TO FT.	LOGGED BY S. MORRISSETTE	CHECKED BY
SIZE AND TYPE OF PACK —	FROM TO FT.		
TYPE OF SEAL GROUT	FROM 0 TO 29.5 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) slightly clayey silty SAND, fine grained, poorly graded, medium dense, moist, 10YR5/3 brown, upper 6 inches gravelly				aedian sand/silt
3		SS	17	5 3 3	PID = ND
4	~~(SC)~~ (SM) silty ~~clayey~~ SAND, fine grained, poorly graded, medium dense, moist, 10YR5/3 brown				Alluvium
5–6		SS	18	3 4 4	PID = ND
7	(SM) silty SAND, fine grained, poorly graded, very dense, moist to very moist, 10YR5/4 yellowish-brown				Alluvium
8		SS	17	12 20 31	PID = ND
9	~~(SC)~~ (SM) silty ~~clayey~~ SAND, fine-grained, poorly graded				Alluvium
10					water enters ATD
11		SS	16	12 11 11	PID = ND
14					water @ 14.0' on drill rods as of 0600 on 7-12-90

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME Coe D.O. 1 HOLE NO. LSB-19

DEPTH (FEET)	DESCRIPTION	SAMPLES: Type No.	Recov. (in)	Penetration Resistance (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: ~~(SC)~~ (SM) silty ~~clayey~~ SAND, fine-grained, poorly graded, medium dense, moist, 10YR5/3 brown				Alluvium
15		SS	18	7 10 12	PID = 1 ppm
17	(CL or SC) Sandy silty clay or clayey SAND, very stiff, low-med plastic, very moist, 10YR /2 grayish-brown to 10YR8/2 white				Alluvium / Denver Fm.
20	with some hard, blocky shale starting at 20 feet	SS	17	11 15 23	Denver Fm. weathered PID = ND weak positive response on MIS blue band test
22					Drilling becomes stiffer at ~23.0'
23	(CH) silty clay ~~SHALE~~, highly plastic, hard, very moist, 10YR6/2 light brownish-gray claystone				Denver Fm
25		SS	16	16 32 44	weak positive response on MIS blue band test PID = ND drilling stopped 7-11-90 Core run #1 drilling resumed 7-12-90
27		CORE	0.75 ft		
29.5					Bottom of boring @ 29.5 feet

Depth scale: 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-020

BORING LOCATION	Sec. 36	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER K Cross	DATE STARTED / DATE FINISHED 7-6-90
DRILLING EQUIPMENT	CME 75	COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST 11 / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 30 FT	

DEPTH (FEET)	DESCRIPTION	Penetration Result (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–7	Clay, very sandy, silty, fine sand, moist, stiff to very stiff, yellowish brown 10YR5/4 (CL)		
2.5–4		8, 9, 9	12.6
5–6.5		9, 13, 16	31.4
7–14	Sand, silty, clayey, medium to fine sand, very moist to wet, medium dense to dense, yellowish brown to brown 10YR5/4, 10YR5/3 (~~SP~~, SM)		
7.5–9		4, 6, 5	0.2
10–11.5		3, 4, 12	32.9

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-020

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15–16								6 9 13	32.8
17–20	Clay, very sandy, stiff, very moist to wet, very dark grayish brown, 10 YR 3/2 (CL)							6 16 27	47.4
21–25	Weathered claystone, sandy, moist, stiff to very stiff, pale brown, blocky 10YR6/3 (CH)							9 14 20	51.6
26–30	Claystone, moist, firm, pale brown 10YR 6/3 (CH)					CORE			5.7

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. LSB-21

BORING LOCATION	LIME SETTLING BASINS	ELEVATION AND DATUM	
DRILLING AGENCY	LAYNE - WESTERN	DRILLER M. WALKER	DATE STARTED / DATE FINISHED 7-10-90
DRILLING EQUIPMENT	CME 750 w/6-5/8" HSA	COMPLETION DEPTH 50.5	SAMPLER 3" OD split spoon
DRILLING METHOD	Hollow stem augers	DRILL BIT	NO. OF SAMPLES: DIST. 11, UNDIST. 1
SIZE AND TYPE OF CASING	—		WATER ELEV.: FIRST 9.5, COMPL. 11, ~~24 HRS~~ 2 HRS
TYPE OF PERFORATION	—	FROM — TO FT.	LOGGED BY; CHECKED BY
SIZE AND TYPE OF PACK	—	FROM — TO FT.	S. MORRISSETTE
TYPE OF SEAL	GROUT	FROM 0 TO 50.5 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4.5	~~(SC)~~ SM ~~slightly clayey to~~ clayey silty SAND, fine-grained, poorly-graded, medium dense, moist, 10YR4/2 dark grayish-brown								Road fill
3						SS	16	10 10 9	PID=ND
4.5–8	(SM) silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR 6/4								Aeolian sand/silt(?)
5.5						SS	18	4 4 3	PID=ND
8–13	~~(ML)~~ (SM) ~~sandy~~ silt, non-plastic, med. dense, v. fine grained sand, wet, 10YR5/3 brown. Sandy Silt					SS	17	3 3 2	PID=ND Alluvium
9.5									water enters ATD
10.5						SS	18	2 2 3	PID=4 ppm water noted on drill rods @ 1138
13–14	(SM) silty SAND, fine-grained, poorly-graded, medium dense, wet, 10YR5/3 brown								Alluvium

PROJECT NO. 89MC114A

SHEET 1 OF 4

Woodward-Clyde Consultants PROJECT NAME ABE D.O. 1 HOLE NO. LSB-21

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(SM) silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR5/3 brown								
15–16						SS	17	8 16 14	PID=ND
20–21						SS	18	4 7 10	PID=ND
24	(SC or CL) clayey SAND or sandy silty CLAY, fine-grained, poorly graded, medium dense, very moist, 10YR5/4 yellowish-brown								Alluvium
25–26						SS	16	6 8 10	PID=ND
28	SANDSTONE: very fine grained, poorly graded, hard to very hard, very moist, 10YR5/3 brown with iron oxide stains, clayey in zones								Denver Fm. weathered drilling fairly rough and difficult to ~47 ft.
30–31						SS	16	16 31 50	PID=ND

PROJECT NO. 89MC114A SHEET 2 OF 4

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-21

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (')	SAMPLES: Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: SANDSTONE: very fine-grained, poorly graded, hard to very hard, very moist, 10YR5/3 brown with iron oxide stains, clayey in zones								Denver Fm. weathered
33									Denver Fm.
34	with some thin seams of highly plastic, silty clay, 10YR4/1 dark gray							14	
35						SS	1.7	33 50	PID=ND
35.5						CORE	2'		CORE RUN #1
44						SS	.4	50/4	PID=ND
47.5									unweathered Denver Fm
48	(CH) silty clay ~~SHALE~~, highly plastic, hard, moist, 10YR5/1 gray to 10YR4/1 dark gray Claystone								Drilling becomes smoother and stiff @48 ft.
49						SS	1.8	15 26 36	PID=ND
50									

PROJECT NO. 89MC114A SHEET 3 OF 4

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-21

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (in)	SAMPLES: Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
50	SAME: (CH) silty clay ~~SHALE~~, highly plastic, hard, moist, 10YR5/1 gray to 10YR4/1 dark gray claystone					SS	18	15 26 36	Denver Fm. unweathered
51									Bottom of boring at 50.5 FEET
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									
68									

84wr11dA

SHEET 4 OF 4

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-22

BORING LOCATION Sec 36		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 07/03/90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 46 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov.	Penetra. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–2	Sand, silty, dry to wet, medium to fine sand, medium dense to dense, light yellowish brown to brown 10YR 6/4 10YR 5/4 10YR 5/3								
2.5–4								9, 11, 11	
5–6.5								7, 7, 7	
7.5–9								6, 6, 7	
10–11.5								7, 15, 18	
14									

PROJECT NO. 89MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-22

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	GRAPHIC LOG Piezometer Installation	Water Content	Piezometer Date	SAMPLES Type No.	SAMPLES Recov. (%)	SAMPLES Penetr. Resist. Blows/6 in.	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								8	
16								9	
								11	
17									
18									
19									
20								4	
								6	
21								9	
22	Clay, silty, sandy, moist, stiff, very pale brown, (CL) 10YR7/4								
23									
24									
25								4	49.7
								7	
26	Sandstone, weathered, silty sand, hard to very hard, yellowish brown (SM)							9	
27									
28									
29									
30								35	10.7
								50/4	
31									
32									

PROJECT NO. 89MC114A

SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-22

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Date	Type No.	Recov.	Penetr. Resist Blows/6 in	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
32									
33									
34									
35								35 50/4	7.4
36									
37	Claystone, hard, silty, dry, blocky, olive, (CH) 5Y5/4								
38									
39									
40								25 35 47	8.2
41									
42						CORE			15.4
43									
44									
45	Sandstone, hard, silty, moist, yellowish brown, (SM) 5Y5/4								
46									

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-23

BORING LOCATION	LIME SETTLING BASINS
DRILLING AGENCY	LAYNE-WESTERN
DRILLER	R. Albritton
DRILLING EQUIPMENT	CME 55 with 6-5/8" HSA
DRILLING METHOD	Hollow STEM AUGERS
DRILL BIT	
SIZE AND TYPE OF CASING	—
TYPE OF PERFORATION	— FROM — TO FT.
SIZE AND TYPE OF PACK	— FROM — TO FT.
TYPE OF SEAL	— Grout FROM —0 TO 44 FT
ELEVATION AND DATUM	
DATE STARTED / DATE FINISHED	6-29-90
COMPLETION DEPTH	44.0
SAMPLER	SPLIT SPOON
NO. OF SAMPLES	DIST. 7 UNDIST.
WATER ELEV.	FIRST 14 COMPL. // 24 HRS.
LOGGED BY	S. MORRISSETTE
CHECKED BY	

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Code	Type No.	Recovery	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine-grained, poorly-graded, medium-dense, dry, 10YR 6/8 yellowish-brown								Aeolian Sand/silt
3						SS	15	4 7 7	PID=ND
5.5						SS	15	3 4 7	PID=ND
7	becomes moist								
8						SS	15	6 6 7	PID=ND
10	color changes to 10YR5/4 yellowish-brown, and becomes very moist and loose (SM) silty SAND, fine-grained, poorly graded, loose, very moist, 10YR5/4 yellowish-brown					SS	14	3 4 3	PID=ND Water level noted on drill rods @ 09:30
14									WATER ENTERS @ 14.0 FEET ATD

PROJECT NO. 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-23

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (")	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Field tests, Odor, etc)
14	SAME: (SM) silty SAND, fine-grained, poorly-graded, medium-dense, wet, 10YR5/4 yellowish-brown								
15						SS	15	9 12 12	PID=ND
20						SS	14	7 14 14	PID=ND
24	(CL) sandy silty clay ~~SHALE~~ claystone, low to medium plastic, weathered, 10YR 5/3 brown								Denver Fm.
25						SS	14	4 8 11	PID=17ppm
26	(CL & CH) silty clay ~~SHALE~~ claystone low, medium & highly plastic, weathered, with some fine grained sand seams, 10YR5/1 gray								Denver Fm
28.5	(SP) slightly silty SANDSTONE, very fine grained, poorly graded, very dense, 10YR5/4 yellowish-brown								Denver Fm CORE RUN #1
29.5						CC	18		PID=ND
30.5	with hard, calcareous concretions at 30.5 feet								SAMPLER MET REFUSAL AT 30.5 FT
31						SS		77/10	
32									

PROJECT NO. 89MC114A

SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. LSB-23

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (ft)	SAMPLES: Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: (SP) slightly silty SANDSTONE, very fine to fine grained, poorly graded, very dense, 10YR 5/4 yellowish-brown								Denver Fm
34									Attempt to core at 34.0 feet met with auger refusal.
39						C			CORE RUN #2
40						O			
41						~~CC~~ 48			
42						R			
43						E			
44	(CH) silty clay ~~SHALE~~, highly plastic, hard, 10YR 4/1 dark gray Claystone								Denver Fm
									Bottom of boring at 44.0 feet

Depth scale: 32–50 feet.

PROJECT NO. 89MC114A

SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-24

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER Kevin Cross	DATE STARTED / DATE FINISHED 6-25-90 / 6-26-90	
DRILLING EQUIPMENT CME 55 with 6-5/8" OD HSA		COMPLETION DEPTH 29.5	SAMPLER 3" OD Split Spoon
DRILLING METHOD Hollow Stem augers	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 14	COMPL. 13 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. Morrissette	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL — Grout	FROM 0 TO 29.5 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recov. ft	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine-grained, poorly graded, medium dense, dry, 10YR 6/4 light yellowish-brown,				Aeolian SAND & SILT
3		SS	12	7 9 9	PID = ND
6		SS	15	9 12 12	PID = ND
8	becomes moist	SS	11	7 10 9	PID = ND
10	~~becomes 10YR 5/3 yellowish-brown~~				Alluvium
11	(SM) silty SAND, fine-grained, poorly graded, medium dense, moist to very moist, 10YR 5/3 yellowish-brown	SS	14	7 8 9	PID = ND
14					

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-24

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: silty SAND (SM), fine-grained, poorly graded, medium dense, wet, 10YR5/3 yellowish-brown								Alluvium
15–16						SS	1.3	8 11 17	PID=ND
20–21						SS	1.8	4 10 12	PID = 2.0ppm
25–26						SS	1.2	10 12 17	PID = 3.2ppm PID in HSA=16ppm
26	WEATHERED ~~SHALE~~: silty CLAY (CH), highly plastic, hard, very moist, 10YR5/1 gray with 10YR5/8 yellowish brown mottling with trace of very fine-grained SAND ~~Sha~~ Claystone					CC #1	3 feet		Denver Fm core run #1
29.5									Bottom of boring at 29.5

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O.1 HOLE NO. LSB-25

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 7-6-90	
DRILLING EQUIPMENT CME 750 w/6-5/8" OD HSA		COMPLETION DEPTH 43.5	SAMPLER 3" OD split spoon
DRILLING METHOD HOLLOW STEM AUGERS	DRILL BIT	NO. OF SAMPLES DIST. 10	UNDIST. 2
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 7.0	COMPL. / 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. MORRISSETTE	
TYPE OF SEAL — GROUT	FROM 0 TO 43.5 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recovery	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine grained, poorly graded, medium-dense, dry to moist, 10YR5/3 brown, upper 0.5 feet gravelly								Fill
1	Fill								
2	(CL) silty CLAY, low to medium plastic, medium stiff, moist, 10YR7/1 light gray								Fill/sludge(?)
3						SS	17	3 2 3	PID=ND
4	Fill								
5									
6						SS	18	2 2 2	PID=ND
7	(SM) silty SAND, very fine-grained, poorly graded, very loose, wet, 10YR3/6 dark yellowish-brown								water enters ATD Alluvium
8						SS	18	1 1 1	PID=ND
9									
10	becomes 10YR5/4 yellowish-brown and medium-dense					SS	15	4 4 5	PID=ND
11									
12									
13									
14									

PROJECT NO. 89MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-25

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Penetration Data	SAMPLES: Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(SM) silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR5/3 brown								Alluvium
16						SS	18	6 7 6	PID=19 ppm
21	(CL) sandy silty CLAY, low plastic, stiff to very stiff, very moist, 10YR5/3 brown					SS	17	6 9 11	PID = 7ppm Alluvium reworked ~~shale~~ claystone
26	(CL to CH) slightly sandy silty clay ~~SHALE~~, low to highly plastic, firm, very moist, 10YR4/1 dark gray with trace of 10YR8/1 white mottling, iron oxide stains, slightly weathered Claystone, weathered					SS	18	7 11 15	PID=ND Denver Fm. weathered
31						CORE	0		Core run #1 no recovery, sampler encounters refusal at 31.5 feet
32	(SP) slightly clayey SANDSTONE, V. fine-grained, poorly graded, hard to very hard, very moist, 10YR5/3 brown, iron oxide stains					SS	9	53 47/3"	Denver Fm weathered PID=ND

PROJECT NO. 84MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. LSB-25

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov.	Penetr. Resist. Bl/6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: (SP) slightly clayey SANDSTONE, fine-grained, poorly graded, hard to very hard, very moist, 10YR5/3 brown, iron oxide stains					SS	9	53 47/3"	Denver Fm weathered
33									
34									
35	becomes very hard					SS	5	115/5"	PID = 22ppm
36									
37									Drilling becomes smoother at 37.5 feet
38	(CH) silty CLAY ~~SHALE~~, highly plastic, hard, very moist, 10YR5/2 grayish-brown to 10YR4/1 dark gray, carbonaceous claystone								Denver Fm
39									
40									
41						SS	16	22 30 49	PID = 72ppm
42	becomes 10YR5/3 brown with iron oxide stains					CORE 2	24		CORE Run #2
43									
44									Bottom of boring at 43.5 feet
45									
46									
47									
48									
49									
50 -50ft									

JECT NO. 84MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-26

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. PARKER	DATE STARTED / DATE FINISHED ~~6-25-90~~ / 6-26-90 / 6-27-90	
DRILLING EQUIPMENT CME 55 with 6-5/8" HSA		COMPLETION DEPTH 34	SAMPLER 3" split spoon
DRILLING METHOD HOLLOW STEM AUGERS	DRILL BIT	NO. OF SAMPLES DIST. 8	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 10	COMPL. 7.5 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. MORRISSETTE	
TYPE OF SEAL — Grout	FROM — 0 TO 34 FT.		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (in)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	~~(SM)~~ silty SAND, fine-grained, poorly graded, medium dense, dry to moist, 10YR5/4 yellowish brown								Fill
1									
2	Fill								
3						SS	12	5 12 16	PID=ND
4									
5	~~(CL)~~ silty CLAY, low to medium plastic, medium to stiff, 10YR8/1 white, moist								Sludge
6	Fill					SS	9	4 4 4	PID=ND
7	(SM) silty SAND, fine-grained, poorly-graded, medium dense, very moist, 10YR 4/4 dark yellowish-brown								water as of 0545 on 6-27-90. Alluvium
8						SS	14	4 4 7	PID=4.0ppm
9									
10	becomes wet					SS	17	3 4 6	Water enters ATD (10 ft) PID=ND
11									
12									
13									
14									

PROJECT NO. 84MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-26

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist. (Bl/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14–18	(SM or ML) silty SAND to sandy SILT, very fine grained, poorly graded, or non-plastic, medium dense, 10YR 5/3 brown, wet								Allluvium
15.5–17						SS	18	7 10 14	PID=ND
18–24	(~~ML to~~ CL) ~~slightly sandy SILT to~~ silty CLAY, non-plastic to low & medium plastic, stiff, wet, 10YR4/3 brown to dark brown								Alluvium
20–21.5						SS	11	3 5 10	PID=7.0ppm
24–30	(CL) slightly sandy silty CLAY, low to medium plastic, stiff to very stiff, wet, 10YR5/3 brown								Reworked ~~Shale~~ Claystone Denver Fm (?)
25–26.5						SS	14	5 10 10	PID=10ppm
30–32.5	(CH) slightly sandy silty CLAY, highly plastic, medium hard, very moist, 10YR4/1 dark gray with some iron oxide staining claystone								Denver Fm.
30–31.5						SS	13	8 16 22	
31.5–32.5	becomes 10YR 5/3 brown and siltier at 31.5 feet to 32.5 feet					CC	36		CORE RUN #1

PROJECT NO. 84MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME Coe D.O. 1 HOLE NO. LSB-26

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Penetrometer Data	SAMPLES: Type No.	SAMPLES: Recov.	SAMPLES: Penetration Resistance (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	SAME: (CH) slightly sandy silty CLAY, highly plastic, medium hard, very moist, 10YR 5/3 brown with some iron oxide staining					CC	36		Denver Fm. Core run #1
33									
34	becomes 10YR 6/2 brownish-gray from 32.5 to 34.0 feet								Bottom of boring at 34.0 feet
35	Claystone								
36									
37									
38									
39									
40									

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-027

BORING LOCATION: Sec 36		ELEVATION AND DATUM:	
DRILLING AGENCY: Layne Western	DRILLER: R. McKay	DATE STARTED / DATE FINISHED: 7-6-90	
DRILLING EQUIPMENT: CME 75		COMPLETION DEPTH: 35	SAMPLER: T. Terry
DRILLING METHOD: Hollow Auger	DRILL BIT:	NO. OF SAMPLES: DIST.	UNDIST.
SIZE AND TYPE OF CASING: NA		WATER ELEV.: FIRST 10	COMPL. 24 HRS.
TYPE OF PERFORATION: NA	FROM TO FT.	LOGGED BY: T. Terry	CHECKED BY:
SIZE AND TYPE OF PACK: NA	FROM TO FT.		
TYPE OF SEAL: Grout	FROM 0 TO 35 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov.	Penetr. Resist. (Blows/6 in.)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–3	Sand, medium to fine sand, trace silt, trace clay, loose to medium dense, dry to wet, yellowish brown to brown, ~~(SP)~~ SM 10YR 5/6, 10YR 5/3								
2.5–4								4, 4, 4	0.2
5–6.5								4, 5, 5	0.2
7.5–9								4, 3, 5	
10–11.5								3, 4, 2	17.4

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

PROJECT NO. 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-027

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist (Blows/6 In)	REMARKS (Drill Rate, Fluid loss, Odor, etc) P.I.D. PPM
14									
15	Clay, slightly sandy, medium stiff, wet, yellowish brown (CL) 10YR5/4							5 5 9	22.6
16									
17									
18									
19									
20								7 11 15	32.4
21	Weathered claystone, blocky, fractured, moist, very stiff to hard, light brownish gray, grayish brown, dark grayish brown (CH) 10YR6/2, 10YR5/2 10YR4/2								
22									
23									
24									
25								11 24 30	155.8
26									
27						CORE			
28									
29									
30	Claystone, moist, hard, very dark grayish brown, grayish brown (CH) 10YR 3/2, 2.5Y5/2					CORE			
31									

SHEET 2 OF 3

...T NO. 89MC114A

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-027

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. ft	SAMPLES: Penetra. Resist (Blows 6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32						CORE			
33									
34									
35									

PROJECT NO. 89MC114A

SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-28

BORING LOCATION	Sec 36	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-2-90
DRILLING EQUIPMENT	CME 75	COMPLETION DEPTH 36	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST 9.0	COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 36 FT.	

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. ft	Penetra. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–2	Sand, silty, clayey, dry, medium dense, brown, ~~(SP)~~ 10YR4/3 (SM)								
3–4								6, 8, 8	5.0
5–6								3, 3, 3	
6	Sand, slightly silty, trace clay, dry, loose, wet, fine sand, yellowish brown ~~(SP)~~ 10YR5/4, 10YR6/4 (SM)								
8–9								3, 5, 9	
9.0	▽								
10–11								3, 2, 1	0.8
12–14									

PROJECT NO. 89MC114A SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-28

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Date	SAMPLES: Type No.	Recov. (ft)	Penetra. Resist (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								5 8 11	49.7
16	Clay, sandy, very stiff, light yellowish brown, moist to very moist, 10YR6/4 (CL)								
17									
18									
19	Weathered claystone, very stiff, moist, light brownish gray, blocky, fractured, 10YR6/2								
20								6 13 18	
21									
22									
23									
24									
25								15 37 39	32.6
26									
27									
28									
29									
30								15 20 20	
31									
32									

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-28

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (')	SAMPLES: Penetr. Resist (Blows 6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32	slightly weathered claystone, hard, moist, dark grayish brown, iron oxide staining, 10YR 4/2					CORE			
33									
34									
35									
36									

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-29

BORING LOCATION Sec 36		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER K. Cross	DATE STARTED / DATE FINISHED 7-5-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH 25	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES / DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. / FIRST	COMPL. / 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 25 FT		

DEPTH (FEET)	DESCRIPTION	Penetra. Resist. (Blow/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4	Clay, very sandy, very moist, fine sand, dark yellowish brown stiff to very stiff (CL) 10YR4/4	5, 10, 11	
4–13	Sand, silty, wet, mostly fine sand, medium dense to dense, dark grayish brown, brown (SP, SM) 10YR 4/2, 10YR 6/4, 10YR5/3	8, 10, 10	3.8
		6, 9, 11	
		5, 6, 8	64.3
13–14			

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-29

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. (!)	Penetr. Resist (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	Weathered claystone, silty, sandy, stiff, dry to moist, pale brown (CH)								
15	10YR 6/3							6 9 14	91.4
16									
17									
18	Claystone, siltstone, little sand, moist, hard, pale brown (CH).								
19									
20	10 YR 4/6 10 YR 4/6							16 28 36	72.4
21									
22									
23									
24									
25									
26									

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-3

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-11-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" HSA		COMPLETION DEPTH 25.5	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow Stem Augers	DRILL BIT	NO. OF SAMPLES DIST. 5	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 7.0	COMPL. 11 ~~24~~ HRS. AD
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. Morrissette	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 25.5 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recovery	Penetration Resistance (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	~~(SC)~~ ~~clayey~~ silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR5/3 brown to 10YR6/3 pale brown								
2	(SM)								
3						SS	18	5 5 6	PID=ND
5	becomes 10YR 5/6 yellowish brown					SS	18	5 6 7	PID=ND
7									water enters ATD
7.5									NOTE: 7.5 FOOT SAMPLE WAS INADVERTENTLY SKIPPED BY DRILLER. WILL NOT ATTEMPT TO RESAMPLE AS TO B&B CLARKS INSTRUCTIONS.
11	becomes 10YR5/4 yellowish-brown and less clayey in zones.					SS	18	6 8 11	PID = 6ppm
14									drilling becomes rougher at 14.0 FEET

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB-30

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. ft	SAMPLES: Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(CH) Sandy silty CLAY, medium to highly plastic, medium hard, very moist to wet, 10YR3/2 very dark grayish-brown to 10YR6/4 light yellowish-brown, very blocky and crumbly, with some seams of very fine grained SANDSTONE								Denver Fm weathered
15						SS	18	8 12 26	PID = 7 ppm
19						SS	16	30 24 24	PID = 59 ppm Denver Fm. unweathered Core run #1
20	(CH) silty clay ~~SHALE~~, highly plastic, medium hard to hard, very moist, 10YR6/3 pale brown to 10YR6/4 light yellowish-brown Claystone					CORE	20 / 132		
25.5									Bottom of boring @ 25.5 FEET

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-31

BORING LOCATION Sec. 36		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-5-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH 30	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES / DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. / FIRST	COMPL. / 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 30 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov.	Penetr. Resist. (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4.5	~~Clay, sandy, silty,~~ very moist, soft, yellowish brown, 10YR5/4 ~~(CL)~~ (SM) Silty Sand with Clay							1, 2, 4	ND
4.5–7	Sand, silty, clayey, wet, medium dense, yellowish brown, (10YR5/4) ~~(SP)~~ (SM)							5, 8, 8	38.1
7–13	Clay, sandy, wet to very moist, stiff, dark brown to dark yellowish brown, 10YR4/4, 10YR4/3 (CL)							6, 8, 11	
								6, 10, 16	11.4
13–14									

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-31

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov. ft	Penetr. Resist Blows/6 in	P.ID. PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	Weathered Claystone, dry little to trace sand, very stiff, dark brown to pale olive (CH) 10YR3/3, 5Y6/3								
15								10	
								17	
16								24	
17									
18									
19									
20								9	
								12	30.4
21								15	
22									
23									
24	Claystone, dry to moist, trace sand, grayish brown, very stiff, (CH) 2.5Y5/2								
25								9	
								18	91.4
26								21	
27									97.4
28									
29									
30									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O. 1 HOLE NO. LSB32

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne-Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-6-90 / 7-9-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" HSA		COMPLETION DEPTH 30 ft.	SAMPLER 3" split spoon
DRILLING METHOD Hollow stem augers	DRILL BIT	NO. OF SAMPLES: DIST. 7	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV.: FIRST 3.5	COMPL. ND / 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. Merrissette	
TYPE OF SEAL Grout	FROM 0 TO 30.0 FT		

DEPTH (FEET)	DESCRIPTION	Sample Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine-grained, poorly graded, med. dense, moist, 10YR 5/3 brown				Fill / aeolian sandy silt
3	becomes very loose	SS	14	1 1 1	PID=ND; water enters ATD
5.5		SS	16	1 1 3	PID=ND
7.5	becomes siltier in zones				
8		SS	18	4 6 9	PID=ND
9	~~(ML) slightly sandy SILT~~, non-plastic, medium dense, very moist, 10YR5/3 brown				Alluvium
10	(SM) silty Sand	SS	16	5 8 10	PID=ND
13	(SC to CL) clayey SAND to sandy silty CLAY, med. dense to stiff, fine grained, poorly graded, very moist, 10YR8/2 white				Alluvium reworked shale

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME GoE D.O.1 HOLE NO. LSB-32

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14–19.5	SAME: (SC to CL) clayey SAND to sandy silty CLAY, med. dense to stiff, fine-grained, poorly graded, very moist, 10YR 8/2 white					SS	17	5 8 10	Alluvium reworked shale PID = 34 ppm
19.5–23	SANDSTONE: (SP) fine-grained, poorly graded, very hard, very moist, 10YR 4/2 dark grayish-brown					SS	8	33 50/3	Denver Fm weathered PID = ND drilling becomes harder at 19.5 ft.
23–26.5	(CL) silty clay ~~shale~~, low to med plastic, very stiff to hard, very moist, 10YR 6/4 light yellowish-brown Weathered Claystone					SS	15	19 36 50/5"	Denver Fm weathered drilling becomes smoother at 23 feet PID = 60-85 ppm Denver Fm Core run #1
26.5–30	(CH) silty clay ~~shale~~, highly plastic, very stiff to hard, very moist, 10YR 6/4 light yellowish-brown to 10YR 5/1 gray Claystone					CORE			
30									Bottom of boring at 30 FEET

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME COE D.O.1 HOLE NO. LSB-33

BORING LOCATION LIME SETTLING BASINS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 7-5-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" OD HSA		COMPLETION DEPTH 41.5	SAMPLER 3" OD split spoon
DRILLING METHOD HOLLOW STEM AUGERS	DRILL BIT	NO. OF SAMPLES DIST. 8	UNDIST. 2
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 7.0	COMPL. 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. MORRISSETTE	
TYPE OF SEAL — Grout	FROM 0 TO 41.5 FT		

DEPTH (FEET)	DESCRIPTION	Type No.	Recovery	Penetration Result (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine-grained, poorly-graded, subangular to subrounded, med. dense, moist, 10YR 5/3 brown, gravelly from 0.0 to 0.5 FT.				aeolian sand/silt
3		SS	16	5 7 5	PID=ND
6	becomes 10YR 4/6 dark yellowish-brown and slightly less silty	SS	15	3 6 8	PID=ND
7	(SP) SAND, fine-grained, poorly graded, subrounded, medium dense, wet, 10YR 5/3 brown, with a trace of silt (SM)				water enters ATD Alluvium
8		SS	13	4 7 11	PID=ND
10	(SM) silty SAND, fine-grained, poorly-graded, dense, wet, 10YR 5/3 brown				Alluvium
11		SS	14	5 14 19	PID=ND

PROJECT NO. 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-~~33~~

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Penetration Scale	SAMPLES Type No.	Recov. (in)	Penetration Resist. (blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(~~ML~~ or SM) ~~sandy SILT~~ or silty SAND, non-plastic, fine-grained, poorly graded SAND, medium dense, wet, 10YR5/3 brown, with trace of clay.								Alluvium
15–16						SS	18	7 10 9	PID=ND
18	(ML) ~~slightly sandy SILT~~, non-plastic, very fine grained, poorly graded SAND, medium dense, very moist, 10YR5/3 brown, iron oxide stains Silty Sand								Alluvium
20–21						SS	18	8 11 16	PID=ND
22	(SM) silty SAND, fine-grained, poorly-graded, medium-dense, very moist to wet, 10YR4/6 dark yellowish-brown								Alluvium
25	(CL to CH) slightly sandy silty clay ~~SHALE~~, very stiff to hard, low to ~~medium~~ highly plastic, very moist, ~~10YR~~ 2.5Y6/4 light yellowish-brown Weathered Claystone					SS	18	9 10 15	Denver Fm. slightly weathered PID=ND
30–31	becomes 2.5Y6/2 light brownish gray, highly plastic, with iron oxide stains, weathered & blocky					SS	18	11 24 36	PID=ND
32						CORE			CORE RUN #1

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-33

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
32–39	SAME: (CH) silty clay ~~SHALE~~, highly plastic, very stiff to hard, very moist, 2.5Y 6/2 light brownish gray, highly weathered, blocky, iron oxide stains Weathered Claystone					CORE #1	48"		Denver Fm. weathered Core run #2
39–41.5	(CH) silty clay ~~SHALE~~, highly plastic, hard, very moist, 10YR 3/1 dark gray, iron oxide stains 41 becomes 10YR 5/4 yellowish-brown claystone					CORE #2	28"		Denver Fm. Bottom of boring at 41.5 feet

Depth scale: 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

PROJECT NO. 89MC114A SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB 34

BORING LOCATION Sec. 36		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 6/26/90 6/27/90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH 46	SAMPLER T. Terry
DRILLING METHOD Hollow Stem	DRILL BIT	NO. OF SAMPLES / DIST.	UNDIST.
SIZE AND TYPE OF CASING 4 in PVC		WATER ELEV. / FIRST	COMPL. / 24 HRS.
TYPE OF PERFORATION 10 Slot	FROM 15.7 TO 25.7 FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK 10-20	FROM 15.4 TO 25.7 FT.	T. Terry	
TYPE OF SEAL Bentonite	FROM 11.5 TO 15.4 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. Ft.	SAMPLES: Penetr. Resist. Blows/6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–5.5	Sand, slightly ~~clayey~~ silty, medium to fine sand, medium dense, moist, dark yellowish brown (~~SC~~) SM 10YR 4/4								
2–3.5								6 8 5	ND
5–6.5								4 3 4	ND
5.5–9.5	Sand, medium to fine sand, silty, loose to medium dense, slightly moist, yellowish brown (SP) 10YR5/4								
7.5–9								4 3 3	ND
9.5–14	Clay, very sandy, medium stiff, slightly moist, ~~yellowish~~ brown, (~~SP~~) ~~10YR5/4~~ (SP) 10YR4/3							4 6 6	ND

PROJECT NO. ~~2050~~ 89MC114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME ______ HOLE NO. LSB-34

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (ft)	SAMPLES: Penetr. Resist (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								6	
16								8	ND
								8	
17									
18	Sand, silty, wet, dense to very dense, grayish brown, 10YR5/2 (SP)								
19									
20								5	
21								11	ND
								14	
22									
23									
24	Clay, sand, very moist, stiff, yellowish brown 10 YR 5/4 (CL)								
25								3	
26								7	ND
								9	
27									
28	Weathered Sandstone, clayey, silty, medium to fine sand, layered, hard to very hard, thin interbedded siltstones < 1 inch, grayish brown, 10YR5/2 (SC)								
29									
30								6	
31								24	ND
								50/4	
32	Denver Formation				S				7.8

PROJECT NO. 89MC114A SHEET 2 OF 3

Woodward-Clyde Consultants PROJECT NAME ____________ HOLE NO. LSB-34

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. ft	Penetr. Resist. Blows 6 in	P.ID. REMARKS PPM (Drill Rate, Fluid loss, Odor, etc)
32						CORE			
33									
34									
35									
36									
37									
38									
39									
40								20 33	5.7
41	Claystone, sandy, silty, slightly moist, slightly blocky, hard, interbedded siltstones and sandstones, dark grayish brown, 10YR 4/2 (CL-CH) Denver Formation							38	
42						CORE			ND
43									
44									
45									
46									

PROJECT NO. 89MC114A

SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME BMA COE HOLE NO. LSB-35

BORING LOCATION Sec 36		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 06/28/30 - 06/29/30	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH 43.5	SAMPLER T. Terry
DRILLING METHOD Hollow Stem	DRILL BIT	NO. OF SAMPLES / DIST.	UNDIST.
SIZE AND TYPE OF CASING 4 in PVC		WATER ELEV. FIRST 9.5	COMPL. 13.3 / 24 HRS.
TYPE OF PERFORATION 10 slot	FROM 19.9 TO 29.9 FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK 10-20 Sand	FROM 14 TO 31 FT.		
TYPE OF SEAL Bentonite	FROM 10 TO 14 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov.	Penetra. Resist. (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4	Sand, very ~~clayey~~ silty, slightly moist, brown, stiff, (SC) 10YR 4/3							3 5 5	ND
4–13.5	Sand, silty, clayey, moist, medium dense, brown, loose, (SP), 10YR4/3, wet yellowish brown 10YR5/4 (SM)							3 6 6	ND
								3 4 4	67
9.5 (water level)								3 4 2	45
14	(Next Page)								

PROJECT NO. 89MC 114A

SHEET 1 OF 3

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-35

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (')	Penetr. Resist. Blows/6 in.	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14	Clay, very sandy, very stiff, wet, grayish brown, wet, (CL), sand zones, 10YR 5/2, pale brown 10YR 6/3							12 17 14	ND
19								7 13 13	ND
24	Clay, sandy, silty, very stiff, moist, light yellowish brown (CL) 10YR 6/4							7 11 12	ND
29	Weathered Claystone, very stiff, moist, dark reddish brown, (CH)							9 13 17	ND
32									

PROJECT NO. 89MC114A

SHEET 2 OF 3

DRAFT

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. LSB-35

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. ft	Penetra. Resist. Blows 6 in.	PID REMARKS PPM (Drill Rate, Fluid loss, Odor, etc)
32	Sandstone, siltstone, interbedded, gray, moist, hard, wet zones 10YR 6/1 (SP)								
33									
34								50/3	37
35								CORE	
36									29
37									
38									
39								CORE	3
40									
41									
42	Claystone, yellowish brown moist, hard, 10YR 5/4 (CL)								
43									

PROJECT NO. 89MC114A

SHEET 3 OF 3

Woodward-Clyde Consultants PROJECT NAME ODE D.O. 7 HOLE NO. LSB-36

BORING LOCATION	LIME SETTLING BASINS
ELEVATION AND DATUM	
DRILLING AGENCY	LAYNE WESTERN
DRILLER	M. WALKER
DATE STARTED / DATE FINISHED	7-12-90
DRILLING EQUIPMENT	CME 750 w/ 6-5/8" HSA
COMPLETION DEPTH	15.5
SAMPLER	3" OD split spoon
DRILLING METHOD	Hollow Stem auger
DRILL BIT	
NO. OF SAMPLES	DIST. 4 / UNDIST. —
SIZE AND TYPE OF CASING	—
WATER ELEV.	FIRST 13 / COMPL. ND / 24 HRS.
TYPE OF PERFORATION	— FROM — TO FT.
SIZE AND TYPE OF PACK	— FROM — TO FT.
TYPE OF SEAL	Grout FROM 0 TO 15.5 FT.
LOGGED BY	S. MORRISSETTE
CHECKED BY	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Plasticity Code	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR7/3 brown Fill							3	Fill
1	(~~SM~~/CL) clayey silty SAND to sandy silty CLAY, fine-grained, poorly graded, medium dense, moist, 5Y7/1 light gray to 5Y6/1 gray					SS	17	3 5	Fill/sludge PID=ND
2	Fill								
3	(SM) silty SAND, fine grained, poorly graded, medium dense, moist, 10YR4/3 brown to dark brown								Fill
4-5						SS	15	3 6 9	PID=ND
9-10						SS	17	7 9 6	PID=ND
12	becomes 10YR5/4 yellowish-brown								
13									water enters ATD
14									

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME OBE 0.0.1 HOLE NO. CSB-36

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: (SM) Silty SAND, fine-grained, poorly graded, Very loose to loose, wet, 10YR 5/4 yellowish-brown					SS	1.6	2 1 3	Fill (?) PID=2.0ppm
15									
16									Bottom of boring at 15.5 FEET
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME GE D.O. 1 HOLE NO. LSB-37

BORING LOCATION Lime Settling Basins		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-12-90	
DRILLING EQUIPMENT CME 750 w/6-5/8" HSA		COMPLETION DEPTH 15.5	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow Stem augers	DRILL BIT	NO. OF SAMPLES DIST. 4	UNDIST. —
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 12.5	COMPL. 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.	S. Morrissette	
TYPE OF SEAL Grout	FROM 0 TO 15.5 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) clayey silty SAND, fine grained, poorly graded, medium dense, moist, 5Y7/1 light gray Fill					SS	15	5 10 7	Fill/sludge PID=ND Fill
1	~~(SM to SC)~~ silty SAND to clayey SAND, fine grained, poorly graded, medium dense, moist, 10YR4/3 brown to dark brown Fill								
4						SS	17	7 5 4	PID=ND
9						SS	18	6 8 8	PID=ND
11	(SM) silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR5/4 yellowish-brown								Alluvium
12									water enters ATD (12.5)

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. LSB-37

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. ft	Penetr. Resist (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: (SM) silty SAND, fine-grained, poorly graded, medium dense, wet, 10YR 5/4 yellowish-brown					SS 10		9 10 10	Alluvium PID=ND
15									Bottom of boring at 15.5 feet
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. MI-01

BORING LOCATION Sec 01		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-13-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST NE	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometric Date	SAMPLES Type No.	Recovery	Penetr. Resist. (Blows/6 in)	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–8.5	Fill, clay, sandy, gravel, bricks, asphalt, very moist, brown							1 2 2	ND
								2 2 2	ND
								Drop 4 3	ND
8.5–11	Sand, silty, clayey, brown, very moist to wet, medium dense							3 5 8	610
11–14	Weathered Claystone, siltstone and sandstone, blocky, stiff crumbly, dark olive gray, dry								

PROJECT NO. 89MC 114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-01

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist Blows 6 in	PID PPM REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								6 4 8	769
16									
17	Claystone, siltstone, sandstone, hard, dry, layered, brown, green								
19									
20								36 50/5	34
21									
22						CORE			0.2
23									
24									
25									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-02

BORING LOCATION	Sec 01	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-16-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST NE	COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry
SIZE AND TYPE OF PACK	NA	FROM TO FT.	CHECKED BY
TYPE OF SEAL	Grout	FROM 0 TO 30 FT.	

DEPTH (FEET)	DESCRIPTION	Penetr. Resist. (blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–9	Clay, little to some sand, dry to moist, brown to yellowish brown, stiff to very stiff	6, 7, 8	ND
		12, 13, 12	ND
		7, 11, 12	ND
9–12	Sand, silty, trace clay, moist, very dense, yellowish brown	11, 14, 18	ND
12–14	Weathered Claystone, very stiff, moist, blocky, fractured, calcareous, dark yellowish brown, olive gray, olive brown, brown		

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-02

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (1)	SAMPLES: Penetra. Resist (Blows 6 in)	PID REMARKS PPM (Drill Rate, Field loss, Odor, etc)
14									
15								16 20 22	1.0
16									
17									
18									
19									
20								11 12 21	1,0
21									
22	Claystone, hard, moist, olive brown, brown								
23									
24									
25						CORE			8.5
26									
27									
28									
29									
30									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-03

BORING LOCATION	Sec 01	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER R. Allbrighton	DATE STARTED / DATE FINISHED 7-16-90
DRILLING EQUIPMENT	CME750	COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV. FIRST 8	COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry
SIZE AND TYPE OF PACK	NA	FROM TO FT.	CHECKED BY
TYPE OF SEAL	Grout	FROM 0 TO 24 FT	

DEPTH (FEET)	DESCRIPTION	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–5	Clay, sandy, fine sand, moist, medium stiff, dark grayish brown (CL) 10YR4/2, ~~10YR~~	3, 4, 4	22
5–7.5	Sand, silty, medium to fine sand, moist, loose, dark yellowish brown (SM) 10YR5/3	2, 1, 2	22
7.5–12	Clay, sandy, moist, very stiff, dark yellowish brown, brown, olive, trace sand, calcareous (CL) 10YR 4/4, 10YR5/3, 5Y5/3	12, 12, 13	700
		9, 12, 17	450
12–14	Weathered Claystone, very stiff to hard, moist, trace sand, blocky, fractured, olive, dark brown, layered (CH) 5Y4/3		

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-03

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov.	SAMPLES: Penetration Resist (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14									
15								20	
								36	25
16								50/5	
17									
18	Claystone, hard, moist, slightly fractured, trace sand, dark brown, layered (CH) 5Y4/3, 10YR3/3								
19									
20								38	ND
								50/5½	
21									
22						CORE			19
23									
24									

PROJECT NO. 89MC114A

SHEET 2 OF 2

MI-04

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. ~~25BORED~~

BORING LOCATION	Sec 01	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-12-90 7-13-90
DRILLING EQUIPMENT	CME 75	COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry
SIZE AND TYPE OF PACK	NA	FROM TO FT.	CHECKED BY
TYPE OF SEAL	Grout	FROM 0 TO 19.5 FT	

DEPTH (FEET)	DESCRIPTION	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–6	Clay, sandy, dry to moist, stiff, brown to dark brown (CL) 10YR3/3, 10YR4/3	3, 8, 7	ND
		5, 5, 4	ND
6–12	Clay, sandy, calcareous, dry, stiff to very stiff, brown, eolian, CL 10YR 5/3	7, 13, 13	ND
		4, 8, 13	4000-Auger 345 Head Space Lewisite Indication
12–14+	Claystone, little to trace sand, hard, moist to very moist, stratified, mostly, very dark grayish brown, also green, blue, olive, dusky red		

PROJECT NO. 89 MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RME HOLE NO. M1-04

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov.	Penetr. Resist (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14									
15						~~15~~		15	
								28	769
16								40	
17						C			34
18						O R			
						E			
19									
20									

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-05

BORING LOCATION Sec 01		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-17-90	
DRILLING EQUIPMENT CME 750		COMPLETION DEPTH 25	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 25 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recovery	Penetration Resist. (Bl/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–11	Sand, clayey, silty, dry to wet, medium dense to very dense, brown, yellowish brown (SP) 10YR4/3, 10YR5/8 10YR5/4								
2.5–4								9 11 14	10 PPM
5–6.5								4 4 6	18 PPM
7.5–9								6 8 15	
10–11.5								13 19 16	133 PPM
11–14	weathered claystone with interbedded siltstones and sandstones, very stiff, moist to very moist, light olive gray, light grayish brown (CH), 5Y6/2, 2.5Y4/2								

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-05

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist (Blows/6 In)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								11	677 PPM
16								16	
								22	
17									
18	Claystone with thin interbedded sondstones and siltstones, hard, moist, grayish brown (CH) 2.5Y 5/2								
19									
20								18	30 PPM
								25	
21								35	
22						CORE			31 PPM
23									
24									
25									

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O.1 HOLE NO. M-16ΦΦ6

BORING LOCATION M-1 PONDS		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 7-13-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" HSA		COMPLETION DEPTH 28.0	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow Stem Augers	DRILL BIT	NO. OF SAMPLES DIST. 7	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST 9.0	COMPL. NR 24 HRS.
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. MORRISSETTE	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL GROUT	FROM 0 TO 28.0 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) gravelly silty SAND, fine-grained, poorly graded, medium dense, dry,								Topsoil
1	(SM) slightly clayey silty SAND, very fine-grained, poorly graded, medium dense, dry to moist, 10YR4/2 dark grayish-brown								Fill(?)
3						SS	15	13 9 8	PID=ND
5						SS	14	5 4 4	PID=ND
7	(SP or SM) slightly silty or silty SAND, fine-grained, poorly graded, subangular to subrounded, medium dense, moist, 10YR6/4 light yellowish-brown								Aeolian sand/silt
8						SS	18	9 8 7	PID=ND
9									water enters ATD (measured)
10	(SC or CL) clayey SAND or sandy silty CLAY, fine-grained, poorly graded, medium dense, moist to very moist, 10YR5/4 yellowish-brown with 10YR8/1 white mottling								Alluvium
11						SS	18	8 10 10	PID=ND to 1ppm
13	(CL) sandy silty CLAY, low plastic, very stiff, moist to very moist, 10YR6/2 light brownish-gray with 10YR8/1 white mottling								Alluvium (reworked bedrock)

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. M-1006

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	(CL) Sandy silty clay ~~SHALE~~, low plastic, hard, moist to very moist, 10YR5/1 gray, very blocky and crumbly, with a trace of coarse gravel. Weathered Claystone								Denver Fm (weathered)
15						SS	18	11 20 31	PID = ND
16									
17									
18									
19									
20	becomes 10YR4/2 dark grayish-brown with less sand and no gravel					SS	18	28 34 50	PID = 15ppm
21									
22									
23									becoming stiffer to drill
24	(CL) slightly sandy silty clay ~~SHALE~~, low-medium plastic, moist, very hard, 10YR4/2 dark grayish-brown and 2.5Y4/N4 dark gray, with iron oxide staining. Claystone					SS	10	28 50/5"	Denver Fm (unweathered) PID = 67-213ppm AsH_3 = 0.5 ppm Dräger = ND Core run #1
25						CORE	3.0 feet		
26									
27									
28									Bottom of boring at 28.0 feet
29									
30									
31									
32									

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME CoE D.O. 1 HOLE NO. M-10007

BORING LOCATION M-1 Ponds		ELEVATION AND DATUM	
DRILLING AGENCY LAYNE-WESTERN	DRILLER R. Albritton	DATE STARTED / DATE FINISHED 7-13-90	
DRILLING EQUIPMENT CME 750 w/ 6-5/8" HSA		COMPLETION DEPTH 26.0	SAMPLER 3" OD split spoon
DRILLING METHOD Hollow Stem Augers	DRILL BIT	NO. OF SAMPLES DIST. 6	UNDIST. 1
SIZE AND TYPE OF CASING —		WATER ELEV. FIRST	COMPL. 24
TYPE OF PERFORATION —	FROM — TO FT.	LOGGED BY S. MORRISSETTE	CHECKED BY
SIZE AND TYPE OF PACK —	FROM — TO FT.		
TYPE OF SEAL GROUT	FROM 0 TO 26.0 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0	(SM) gravelly silty SAND, fine-grained, poorly graded, medium dense, dry Fill								Fill
1	(SC) clayey silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR4/2 dark grayish-brown								Fill
2									
3	Fill					SS	15	8 9 8	PID = ND
4									
5	becomes 10YR3/2 very dark grayish-brown					SS	18	4 4 7	PID = ND
6									
7	(CH) slightly sandy silty CLAY, highly plastic, stiff, very moist, 10YR 2/2 very dark brown with trace of fine grained SAND								Fill
8						SS	18	5 6 7	PID = 0.5 ppm
9	Fill								
10	(SC) clayey silty SAND, fine-grained, poorly graded, medium dense, moist, 10YR5/3 brown with 10YR8/2 white mottling								Alluvium water
11						SS	18	7 16 16	PID = ND
12									
13	becomes more clayey to 14.5 ft.								
14									

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME CE D.O. 1 HOLE NO. M-10007

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	SAME: (see previous page)								Alluvium
15	(SANDSTONE and SC) fine-grained, poorly graded, medium hard, moist, 10YR5/1 gray, slightly silty SANDSTONE with clayey silty SAND					SS	18	8 14 19	Denver Fm (weathered) PID=0.8ppm
20						SS	17	20 25 22	PID=ND
22	(CL w/ML) silty CLAY ~~SHALE~~ and slightly sandy SILTSTONE, low-med plastic, hard, moist, 10YR5/1 gray and 10YR5/3 brown, with trace of very fine-grained SAND Claystone					CORE	4 feet		Core run #1 Denver Fm (unweathered)
26									Bottom of boring at 26.0 feet

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-08

BORING LOCATION Sec 01		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-19-90.	
DRILLING EQUIPMENT CME 750		COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD Cont. Coring	DRILL BIT	NO. OF SAMPLES: DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV.: FIRST	COMPL. / 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 20 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Penetrometer Scale	SAMPLES: Type No.	Recovery	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–11	Fill, clay, sandstone, claystone, blocky, mixed, wet, olive gray, grayish brown, 5Y4/2, 10YR5/2 10YR4/2							7 10 23	31.6
								11 10 10	12.6
								5 10 14	16.1
								8 13 18	21.9
11–14	Claystone with thin interbedded sandstone lenses, hard, moist, grayish brown, green, reddish yellow, yellow, light gray, stratified, gravelly								

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-08

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov.	SAMPLES: Penetra. Resist (Blows 6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									
15								27	
								36	221
16								38	
17									36.8
18						CORE			
19									
20									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. MI-09

BORING LOCATION Sec. 01		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7/17/90 - 7/18/90	
DRILLING EQUIPMENT CME 750		COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD HOLLOW AUGER	DRILL BIT	NO. OF SAMPLES · DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. · FIRST	COMPL. · 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL ~~NA~~ Grout	FROM 0 TO 19.5 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Date	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–11	Clay, little to some sand, moist, stiff to very stiff, dark yellowish brown, light yellowish brown, pale brown (CL) 10YR 3/4, 10YR6/4, 10YR6/3							6 7 8	1533
								4 4 6	202
								6 9 11	~~2525~~ ~~Lewisite~~
								7 10 12	~~73000~~ 2525 Lewisite Indication
11–14	Weathered claystone, moist, very stiff to hard, grayish brown, layered (CH) ~~to~~ 2.5YR5/2								

PROJECT NO. 89 MC 114 A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-09

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	GRAPHIC LOG Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	SAMPLES Recov.	SAMPLES Penetr. Resist (Blows 6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14	Claystone, moist, hard to very hard, grayish brown, layered (CH) 2.5YR 5/2							27	
								37	73000
15								50/5	
16									314
17						CORE			
18									
19									
20									

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-10

BORING LOCATION Sec 1		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-11-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH 20	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 20 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. ft.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–11	Fill Clay, little sand, gravel in 10 ft. sample, moist to very moist, very dark gray to dark brown, 10YR3/1, 10YR3/2, 10YR3/3							6 8 10	72
								3 3 6	767
								5 8 12	
								3 12 17	767
11–14	Claystone, moist to very moist, firm to hard, weathered in top 1 foot								

PROJECT NO. 89MC114A SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-10

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov. (ft)	SAMPLES: Penetra. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14									
15								18	1754
								40	342
16								42	
17						CORE			
18									
19									
20									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-11

BORING LOCATION Sec 1		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER B. McKay	DATE STARTED / DATE FINISHED 7-11-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH ~~20~~ 19	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 19 FT		

DEPTH (FEET)	DESCRIPTION	Penetr. Resist. (Blws/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–7	Fill, clay, sandy moist to very moist, very dark grayish brown to dark gray 10YR3/2, 10YR3/1	4, 7, 5	230
		3, 5, 9	45
7–11	Clay, sandy, calcareous, dry to moist, stiff to very stiff, yellowish brown 10YR5/4, 2.5Y5/4	5, 8, 11	57
		6, 8, 14	24.4
11–14	Claystone, trace silt, trace to little sand, firm to very hard dark olive gray, blueish 5Y3/2		

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. MI-11

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recov.	SAMPLES: Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14									
15								20	6.3
								40	
16								50/5	
17						CORE			
18									
19									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-12

BORING LOCATION	Sec 1
DRILLING AGENCY	Layne Western
DRILLER	R. McKay
DRILLING EQUIPMENT	CME 75
DRILLING METHOD	Hollow Auger
DRILL BIT	
SIZE AND TYPE OF CASING	NA
TYPE OF PERFORATION	NA FROM TO FT.
SIZE AND TYPE OF PACK	NA FROM TO FT.
TYPE OF SEAL	Grout FROM 0 TO 21.5 FT
ELEVATION AND DATUM	
DATE STARTED / DATE FINISHED	7-12-90
COMPLETION DEPTH	
SAMPLER	T. Terry
NO. OF SAMPLES	DIST. / UNDIST.
WATER ELEV.	FIRST / COMPL. / 24 HRS.
LOGGED BY	T. Terry
CHECKED BY	

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Date	Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–11	Clay, sandy, moist, stiff to very stiff, brown, dark grayish brown, dark yellowish brown (CL) 10YR4/3, 10YR4/2, 10YR4/4, 10YR5/4								
2.5–4						SS		3 6 7	0.4
5–6.5						SS		4 7 8	ND
7.5–9						SS		4 9 8	ND
10–11.5						SS		9 12 16	27
11–13	weathered Claystone, very stiff, moist to dry, yellowish brown, light olive brown 10YR 5/4 2.5Y4/4 (CH)								
12.5–14								10 13 21	296

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-12

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (%)	Penetra. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14	Claystone, hard to very hard, dry to moist, olive brown (CH), 2.5Y4/4								
15								36 44 50/5	24
17						CORE			
19									
20									
21									
22									
23									
24									
25									

PROJECT NO. 89MC114A

SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-13

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER R Allbritton	DATE STARTED / DATE FINISHED 7-18-90 / 7-19-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD	Continuous CORE	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 20 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Placement Date	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.) PID PPM
0–2	Fill, Clay, gravelly, moist brown 10YR6/4					GT, GS			31.6
2–8	Sludge, light gray, layered white, black, wet, 10YR7/1								12.6
						GS, C			16.1
8–9	Clay, light yellowish brown, wet, 10YR 6/4 (CL)								
9–14	Weathered claystone, blocky, dark yellowish brown (CH) 10YR4/4					GS, C, GT			21.9

PROJECT NO 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-13

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc) PID PPM
14									
15						C			221 Mustard Indication
16	Claystone, hard, moist, brown layered, 10YR4/3								
17									
	Sheared in Tube								
18						GT			36.8
19									
20									
									core samples GT - Geotech GS - Geosafe C - Chemical

PROJECT NO. 89MC114A

SHEET 2 OF 2

DRAFT

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-14

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-2~~3~~4-90 / 7-25-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH 20	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 20 FT	

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Penetrometer Data	Samples: Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–3	Fill, Gravel, clay, moist, brown, 10YR4/3					T A G			
3–8	Sludge, moist, gray, white, black,					A C G			2727 PPM ~~292 PPM~~ Lewisite Indication. 30 PPM Lewisite Indication
8–12	Clay, moist, sandy, gravelly, light brownish gray, (CL) 10YR6/2					A T G C			~~5798 PPM~~ 919 PPM
12–14	Weathered Claystone, moist to dry, calcareous, blocky, fractured, (CH), 10YR3/3								

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-14

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14						A			
						C			
15									2052 PPM
16									
17	Claystone, ~~brown~~, moist, slightly fractured, very dark grayish brown 10YR 3/2								
18						T			
19									919 PPM
20									Core Samples T - Geotech A - Army G - Geosafe C - Chemical

PROJECT NO. 89MC114A SHEET 2 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-15

BORING LOCATION	Sec. 1
DRILLING AGENCY	Layne Western
DRILLER	M. Walker
DRILLING EQUIPMENT	CME 750
DRILLING METHOD	Continuous Core
DRILL BIT	
SIZE AND TYPE OF CASING	NA
TYPE OF PERFORATION	NA — FROM TO FT.
SIZE AND TYPE OF PACK	NA — FROM TO FT.
TYPE OF SEAL	Grout — FROM 0 TO 20 FT.
ELEVATION AND DATUM	
DATE STARTED / DATE FINISHED	7-19-90 / 7-23-90
COMPLETION DEPTH	20
SAMPLER	T. Terry
NO. OF SAMPLES	DIST. — UNDIST.
WATER ELEV.	FIRST — COMPL. — 24 HRS.
LOGGED BY	T. Terry
CHECKED BY	

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer installation	Water Content	Placement Date	SAMPLES Type No.	Recovery	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4	Fill, gravel, clayey, dark yellowish brown, moist 10 YR3/4					Grout; A; G (1–2 ft)			14.5 PPM (at 4 ft)
4–8.5	Sludge, wet, gray, black, white, red					A; G; C (6–7 ft)			
8.5–12	Clay, wet to moist, brown					A; G; C (9–10 ft)			1736 PPM Lewisite Indication 919 PPM
12–14	Weathered claystone, wet to moist, brown, highly fractured, blocky								

89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-15

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (ft)	Penetr. Resist Blows 6 in	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14						A			
15						C			2052
16									
17	Claystone, moist, brown, sl. fractured								
18						GEOT			
19									919
20									

Core Samples

Army – A

Geosafe – G

Chemical – C

Geotech – Geot

89MC114A

2 of 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-16

BORING LOCATION Sec 1		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-26-90	
DRILLING EQUIPMENT CME 750		COMPLETION DEPTH 8	SAMPLER T. Terry
DRILLING METHOD Cont. Core	DRILL BIT	NO. OF SAMPLES / DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. / FIRST	COMPL. / 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 8 FT		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Sample No.	Recovery	Penetration Resist.	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–1	Roadbase, Gravel Sandy, ~~brown~~, dry very dark gray				A G			
1–4	Clay, very moist, brown, ~~stif~~ stiff							
4–7.5	Sludge, gray, very moist,				A G			0.3 PPM
7.5–8	Sand, clayey, moist, verydense				A G			611 PPM Rig Refusal

PROJECT NO. 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-17

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-26-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES / DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV. / FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Penetration Data	SAMPLES: Type No.	Recovery	Penetration Resist. (Blows/6 in.)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–3	Fill, clay, gravel, sandy moist, very dark grayish brown 10YR3/2					A, G (~1–1.5)			
3–8	Sludge, gray, white, brown very moist					G, A (~5–5.5)			93 PPM
8–10	Clay, moist, stiff, (CL) dark yellowish brown 10YR 4/4					A, G (~9–9.5)			2683 PPM Lewisite Indication

PROJECT NO. 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-18

BORING LOCATION Sec 1		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-26-90	
DRILLING EQUIPMENT CME 750		COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD Cont. Core	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 10 FT.		

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Piezometer Data	Type No.	Recovery	Penetr. Resist. (Blows/6 in.)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4	Clay, dry to moist, stiff, dark yellowish brown, 10YR 4/4 (CL)					G, A (at 1–2 ft)			
4–10	Clay, very sandy, moist to very moist, brown 10YR 5/3, (CL)					A, G (at ~7 ft); A, G (at ~9–10 ft)			77 PPM (at ~5 ft); 3.49 PPM (at ~10 ft)

PROJECT NO. 89 MC114 A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-19

BORING LOCATION	Sec 1		ELEVATION AND DATUM
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-23-90
DRILLING EQUIPMENT	CME 750		COMPLETION DEPTH / SAMPLER
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA		WATER ELEV. FIRST / COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 15 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Piezometer Cells	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 In)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–4	Clay, moist, sandy, soft to stiff					A G (1–2)			
4–7.5	Sand, silty, clayey, wet, loose, brown					A G (~7)			947 PPM
7.5–12	Clay, sandy, moist to wet, calcareous (aeolian), stiff to very stiff, brown, pale brown								2054 PPM Lewisite Indication
12–14	Sand, silty, wet, trace clay, mediumdense, brown								

PROJECT NO. 89MC114A

SHEET 1 OF 2

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. MI-19

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Piezometer Data	SAMPLES Type No.	Recov. (%)	Penetra. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc)
14									605 PPM
15									

PROJECT NO. 89MC114A

SHEET 2 OF 2

DRAFT

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. MI-20

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-27-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	SAMPLES	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–2.5	Fill, clay, gravelly, moist, stiff, dark, yellowish brown 10YR 4/4	A, G (~2 ft)	
2.5–7.5	Sludge, ~~san~~ gray, soft, white, brown, moist	A, G (~4.5 ft)	47PPM
7.5–10	Clay, sandy, stiff, moist yellowish brown 10YR5/4	G, A (~8 ft)	189 PPM

89 MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-21

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-27-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY: T. Terry
SIZE AND TYPE OF PACK	NA	FROM TO FT.	CHECKED BY
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	SAMPLES (Type No.)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–1	Road base, gravel, sand, clayey, very dense, dry Fill		
1–4.5	Fill Gravel, sandy, clayey, dry to moist, brown (GP) 10YR 4/3	A, G (approx. 2.5–3)	
4.5–8	Sludge, gray, brown, moist, soft	A, G (approx. 6.5–7.5)	50 PPM
8–10	Clay, very stiff, dry, dark brown, (CL) 10YR3/3	G, A (approx. 8–8.5)	137 PPM
10			

Core Sample
G - Geosafe
A - Army

PROJECT NO. 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-22

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-27-90
DRILLING EQUIPMENT	CME 750		COMPLETION DEPTH 10 · SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES · DIST. · UNDIST.
SIZE AND TYPE OF CASING	NA		WATER ELEV. · FIRST 4.5 · COMPL. · 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry · CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Penetration Data	SAMPLES: Type No.	Recovery	Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–3	Fill, sand, clean, to gravelly, to clayey, loose, moist to wet, brown, medium to fine sand, poorly graded (SP) 10YR4/3								
2						A			
						G			
						T			
3	very loose								
5									140 PPM
9.5						A			107 PPM
						G			
10									

Core Sample
G - Geosafe
A - Army
T - Geotech

~~89C114~~ 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-23

BORING LOCATION	Sec 1		ELEVATION AND DATUM
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-23-90
DRILLING EQUIPMENT	CME 750		COMPLETION DEPTH 10 / SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA		WATER ELEV.: FIRST / COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	Lithology	Piezometer Installation	Water Content	Placement Data	Samples: Type No.	Recovered	Penetration	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–1.5	Fill Gravel, clayey, moist, light yellowish brown, 10YR6/4 (GC)								
1.5–5	Fill, clay, moist, sandy, brown 10YR4/3 (CL)					A, G			4 PPM; 10 PPM
5–8.5	Sludge, gray, black, white, blocky, moist, soft					A, G			
8.5–10	Clay, dark brown, moist 10YR3/3 (CL)					A, G			~~15~~ 13 PPM

Core Samples
G - Geosafe
A - Armylab

PROJECT NO. 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-24

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-25-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	SAMPLES Type No.	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–1.3	Fill, Gravel, clay, moist, dark brown, 10YR 3/3	A, G	
1.3–8	Sludge, gray, white, black, ~~soft~~ moist to dry, soft	T, A (5); A, G (7)	0 PPM
8–10	Clay, sandy, moist, stiff, yellowish brown, (CL) 10YR 5/6	A, G (9)	130 PPM

CORE Samples
G - Geosafe
A - Army
T - Geotech

PROJECT NO. 89MC114A SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. MI-25

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-24-90.
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. / 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Pressure Data	SAMPLES: Type No.	Recovery	Penetration Resist. Blows/6 In.	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–2	Fill, Gravel, clayey, sandy, moist, brown, 10YR4/3					A, G			
2–4.5	Sludge, gray, brown, white dry to moist					A, G			292 PPM
4.5–10	Clay, little to trace sand, moist, dark gray, 10YR4/1					A, G			5798 PPM
									CORE Samples G - Geosafe A - Army

PROJECT NO. 89MC114A SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-26

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-25-90
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL.	24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry
SIZE AND TYPE OF PACK	NA	FROM TO FT.	CHECKED BY
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Penetration Data	SAMPLES: Type No.	Recovery	Penetration Resist. (Blows/6 in.)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–2	Fill, gravel, sand, clay, brown 10YR5/3					A G			
2–8	Sludge, moist, gray, white, black					A G			0 PPM
8–10	Clay, sandy, brown, moist 10YR5/3					A G			767 PPM Lewisite Indication

89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-27

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-27-90
DRILLING EQUIPMENT	CME 750		COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD	Cont. Core	DRILL BIT	NO. OF SAMPLES DIST. UNDIST.
SIZE AND TYPE OF CASING	NA		WATER ELEV. FIRST COMPL. 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG Lithology	Piezometer Installation	Water Content	Pocket Pen.	SAMPLES Type No.	Recovery	Penetr. Resist.	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–2	Fill, gravel, clayey, brown 10YR4/3					A G			
2–5	Sludge, gray, soft, moist								25 PPM
5–10	Clay, very stiff, moist, olive brown, olive, (CH) 2.5Y4/4, 5Y4/3					A G			103 PPM

89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-28

BORING LOCATION Sec 1		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER M. Walker	DATE STARTED / DATE FINISHED 7-26-90.	
DRILLING EQUIPMENT CME 750		COMPLETION DEPTH 10	SAMPLER T. Terry
DRILLING METHOD Cont. Core	DRILL BIT	NO. OF SAMPLES DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 10 FT		

DEPTH (FEET)	DESCRIPTION	Samples	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–3.5	Fill, gravel, clay, moist, sandy, light, yellowish brown, 10YR6/4	G, A (~0.5–1 ft)	
3.5–10	Clay, sandy, calcareous, moist, dark grayish brown 10YR4/2 (CL)	G, A (~5–5.5 ft); A, G (~9–9.5 ft)	0 PPM (~5 ft); 229 PPM (~10 ft)

Core Samples
G - Geosafe
A - Army

PROJECT NO. 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. M1-29

BORING LOCATION	Sec 1	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER	M. Walker
DATE STARTED / DATE FINISHED	7-24-90		
DRILLING EQUIPMENT	CME 750	COMPLETION DEPTH	10
SAMPLER	T. Terry		
DRILLING METHOD	Cont. Core	DRILL BIT	
NO. OF SAMPLES	DIST.	UNDIST.	
WATER ELEV.	FIRST	COMPL.	24 HRS.
SIZE AND TYPE OF CASING	NA		
TYPE OF PERFORATION	NA	FROM TO FT.	
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 10 FT	
LOGGED BY	T. Terry	CHECKED BY	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Placement Data	SAMPLES: Type No.	Recovery	Penetration Resist. (BL/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–5	Fill, gravel, little clay, moist to wet								0.6 PPM
5–7.5	Clay, moist to wet, stiff, brown 10YR4/3					A G			
7.5–10	Clay, sandy, wet, very stiff, dark grayish brown 7.5YH/2					A G			111 PPM

Core samples
G - Geosafe
A - Army

PROJECT NO. 89MC114A

SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. 25BORE00(

BORING LOCATION Sec. 25		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-10-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH 6	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES — DIST. 1	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV. — FIRST	COMPL. — 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 6 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Placement Data	SAMPLES: Type No.	Recov. (ft)	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–5.5	Clay, moist to very moist, brown, (CH), 10YR 4/3					GRAB			
6	Sand, clayey, medium to fine sand, very moist, (SC) brown, 10YR4/3								

PROJECT NO. SHEET ____ OF ____

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. 25BORE007

BORING LOCATION	~~Layne Western~~ Sec. 25	ELEVATION AND DATUM	
DRILLING AGENCY	Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-10-90
DRILLING EQUIPMENT	CME 75	COMPLETION DEPTH	SAMPLER T Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST / COMPL. 24 HRS.	
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY T. Terry / CHECKED BY
SIZE AND TYPE OF PACK	NA	FROM TO FT.	
TYPE OF SEAL	Grout	FROM 0 TO 6 FT	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	GRAPHIC LOG: Piezometer Installation	Water Content	Piezometer Data	SAMPLES: Type No.	SAMPLES: Recovery	SAMPLES: Penetration Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–6	Clay, moist to very moist, brown, (CH) 10YR 4/3					GRAB			

Depth scale: 1, 2, 3, 4, 5, 6

PROJECT NO. SHEET 1 OF 1

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. 25BORE008

BORING LOCATION Sec. 25		ELEVATION AND DATUM	
DRILLING AGENCY Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-10-90	
DRILLING EQUIPMENT CME 75		COMPLETION DEPTH	SAMPLER T. Terry
DRILLING METHOD Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST.	UNDIST.
SIZE AND TYPE OF CASING NA		WATER ELEV.: FIRST	COMPL. 24 HRS.
TYPE OF PERFORATION NA	FROM TO FT.	LOGGED BY T. Terry	CHECKED BY
SIZE AND TYPE OF PACK NA	FROM TO FT.		
TYPE OF SEAL Grout	FROM 0 TO 6 FT		

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Placement Date	SAMPLES: Type No.	Recovery	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–6	Clay, moist to very moist, brown (CL) 10YR4/3					GRAB			

SHEET ____ OF ____

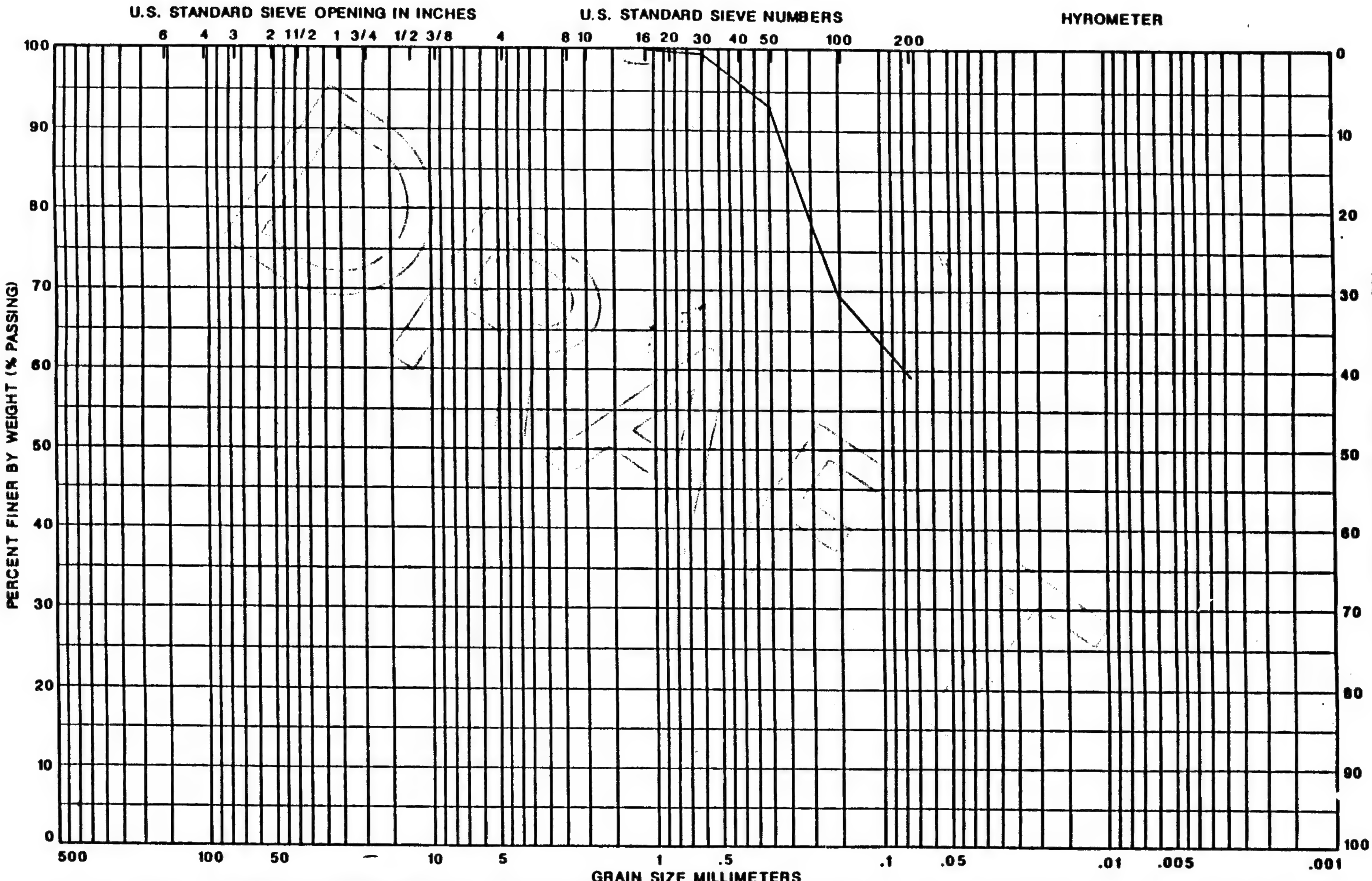
PROJECT NO. ________

Woodward-Clyde Consultants PROJECT NAME RMA COE HOLE NO. 25BORE00

BORING LOCATION	Sec 25	ELEVATION AND DATUM	~~7-10~~
DRILLING AGENCY	Layne Western	DRILLER R. McKay	DATE STARTED / DATE FINISHED 7-10-90
DRILLING EQUIPMENT	CME 75	COMPLETION DEPTH 6	SAMPLER T. Terry
DRILLING METHOD	Hollow Auger	DRILL BIT	NO. OF SAMPLES: DIST. / UNDIST.
SIZE AND TYPE OF CASING	NA	WATER ELEV.: FIRST	COMPL. / 24 HRS.
TYPE OF PERFORATION	NA	FROM TO FT.	LOGGED BY: T. Terry
SIZE AND TYPE OF PACK	NA	FROM TO FT.	CHECKED BY
TYPE OF SEAL	Grout	FROM 0 TO 6 FT.	

DEPTH (FEET)	DESCRIPTION	GRAPHIC LOG: Lithology	Piezometer Installation	Water Content	Placement Date	SAMPLES: Type No.	Recov.	Penetr. Resist. (Blows/6 in)	REMARKS (Drill Rate, Fluid loss, Odor, etc.)
0–6	Clay, moist, brown (CL) 10YR 4/3					GRAB			
6									

PROJECT NO. ______ SHEET 1 OF 1

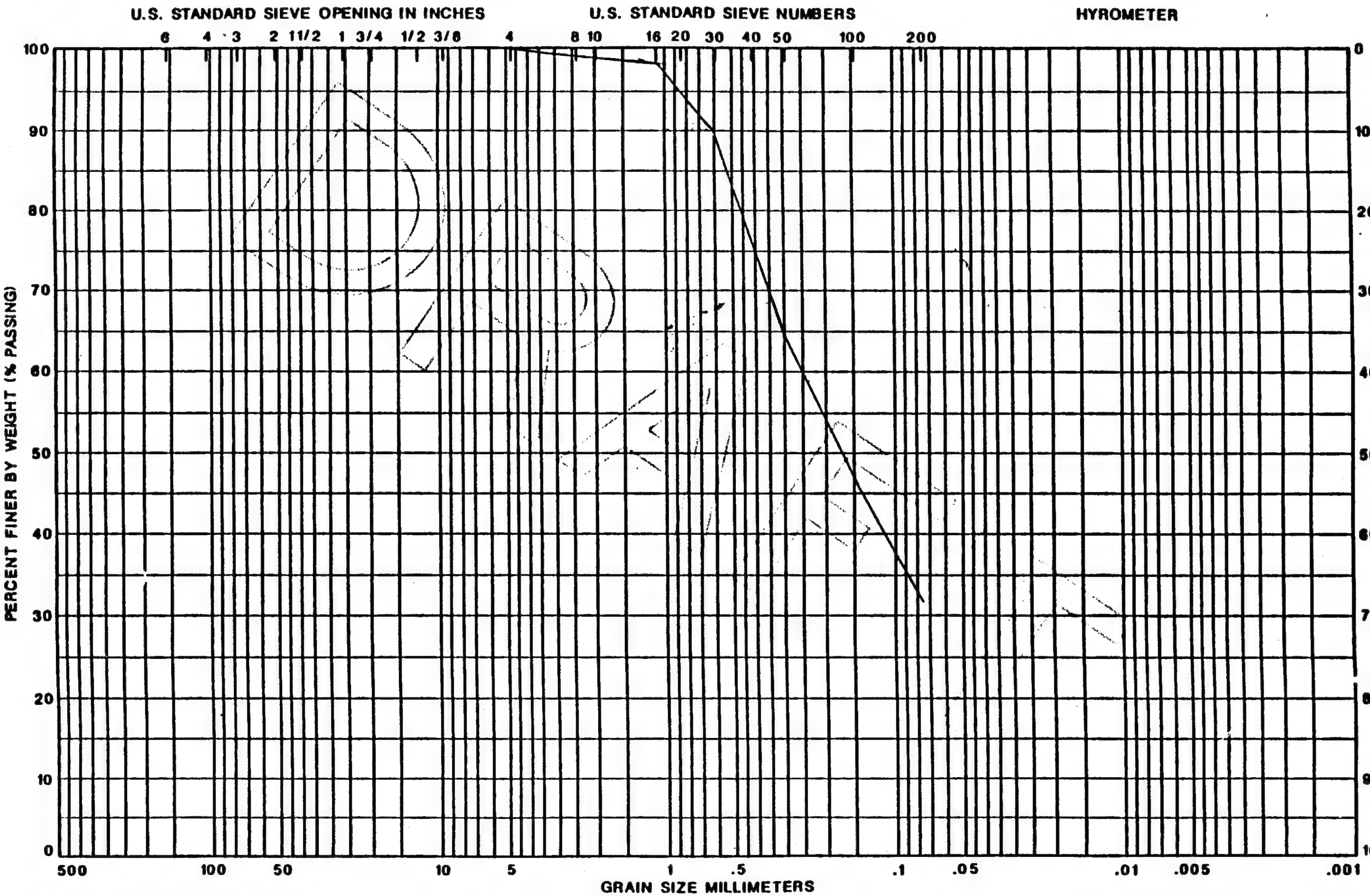


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

PLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	W	LL	PL	PI
CC 0009	7.5'-9.0'	CL	SANDY LEAN CLAY	8	26	10	16

Woodward-Clyde Consu

MC114A

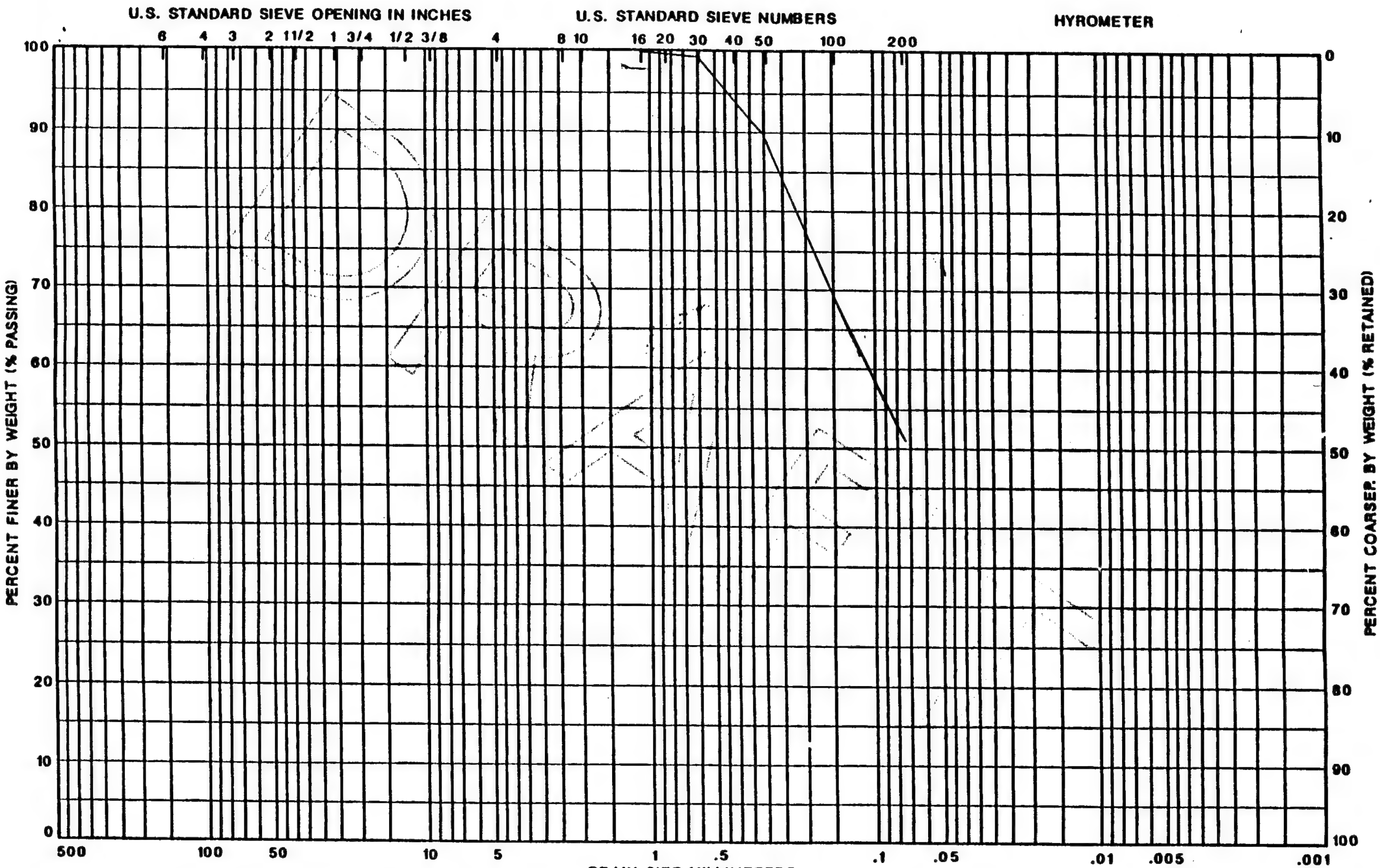


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
SB-0010	2.5'	SM	SILTY SAND	10.5	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

80MC114A

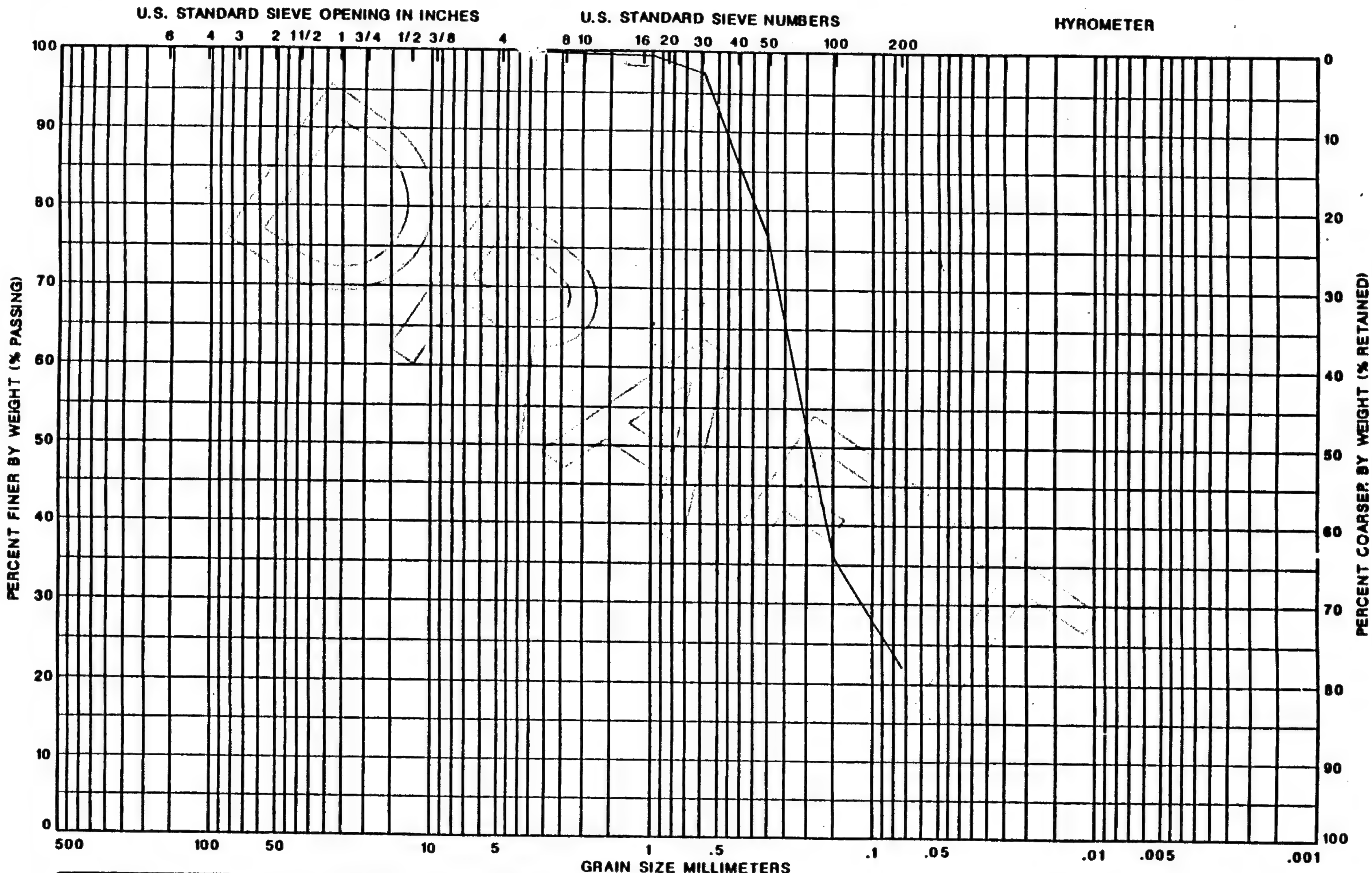


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COE[illegible]010	2.5'-6.5'	CL	SANDY LEAN CLAY	[illegible]	41	22	19

Woodward-Clyde Consult[illegible]

MC114A

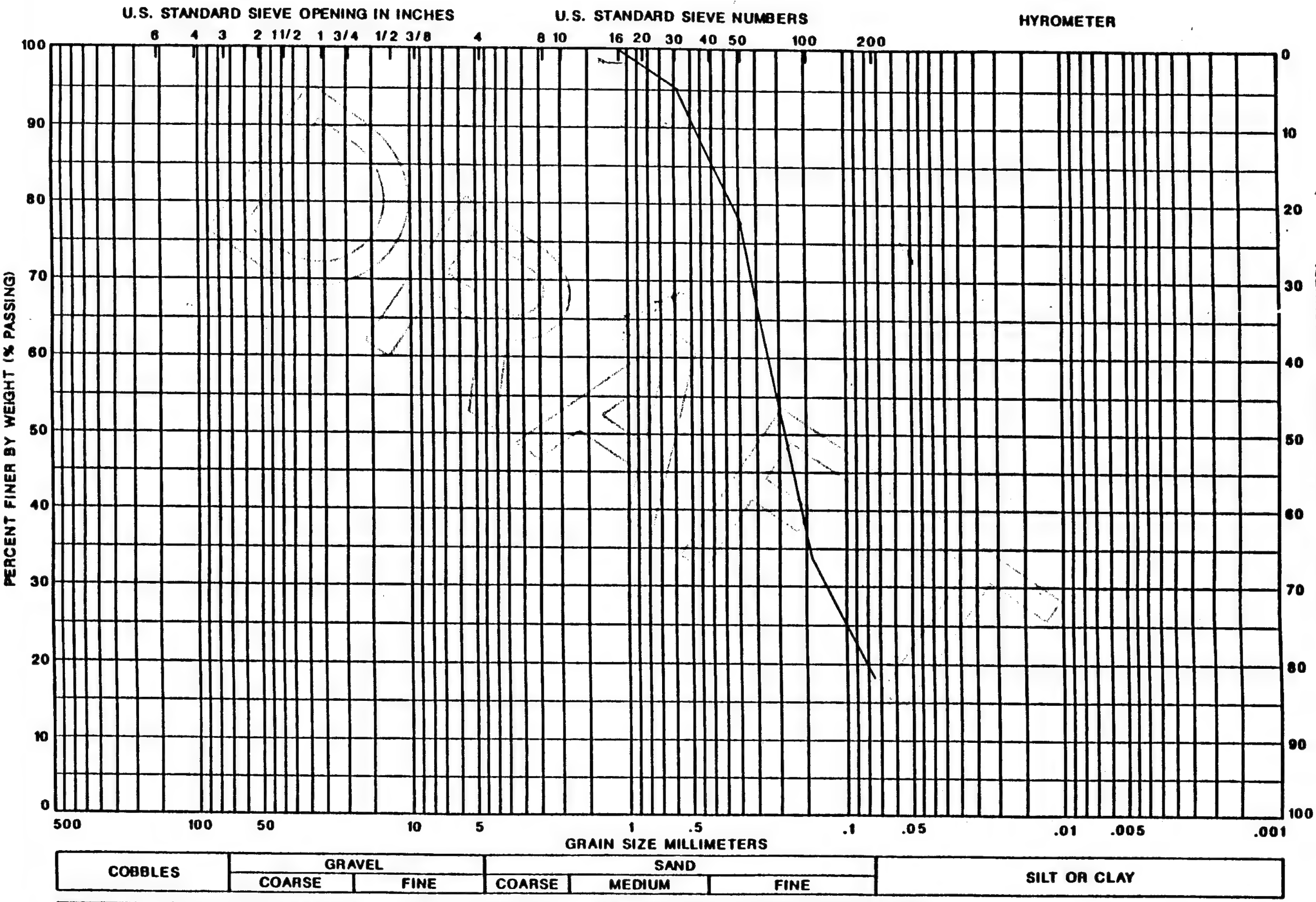


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0010	7.5'-9.0'	SM	SILTY SAND	2.8	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

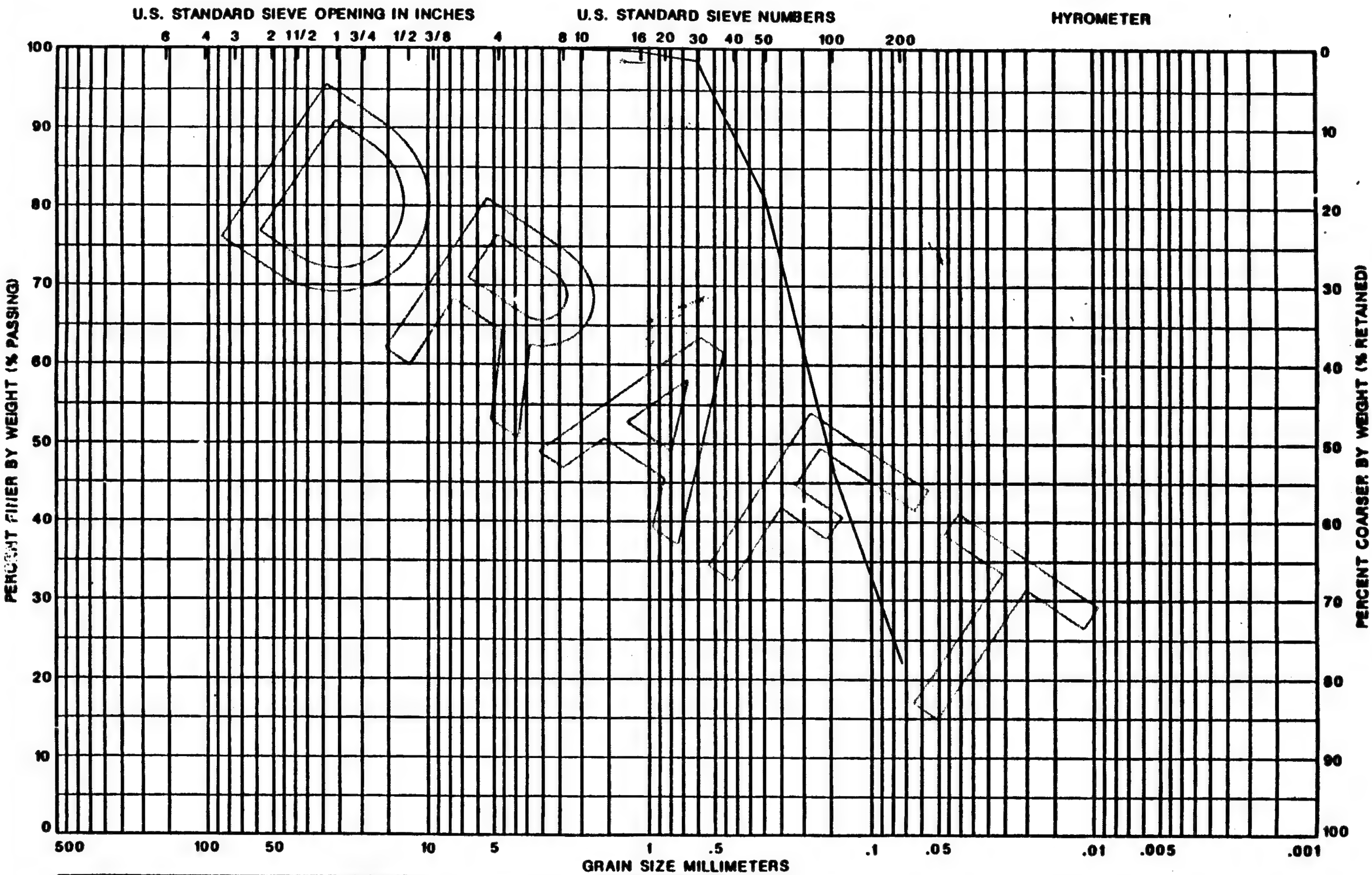
89MC114A



SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COE 0015	2.5'	SM	SILTY SAND	3	N.P.	N.P.	N.P.

Woodward-Clyde Consul

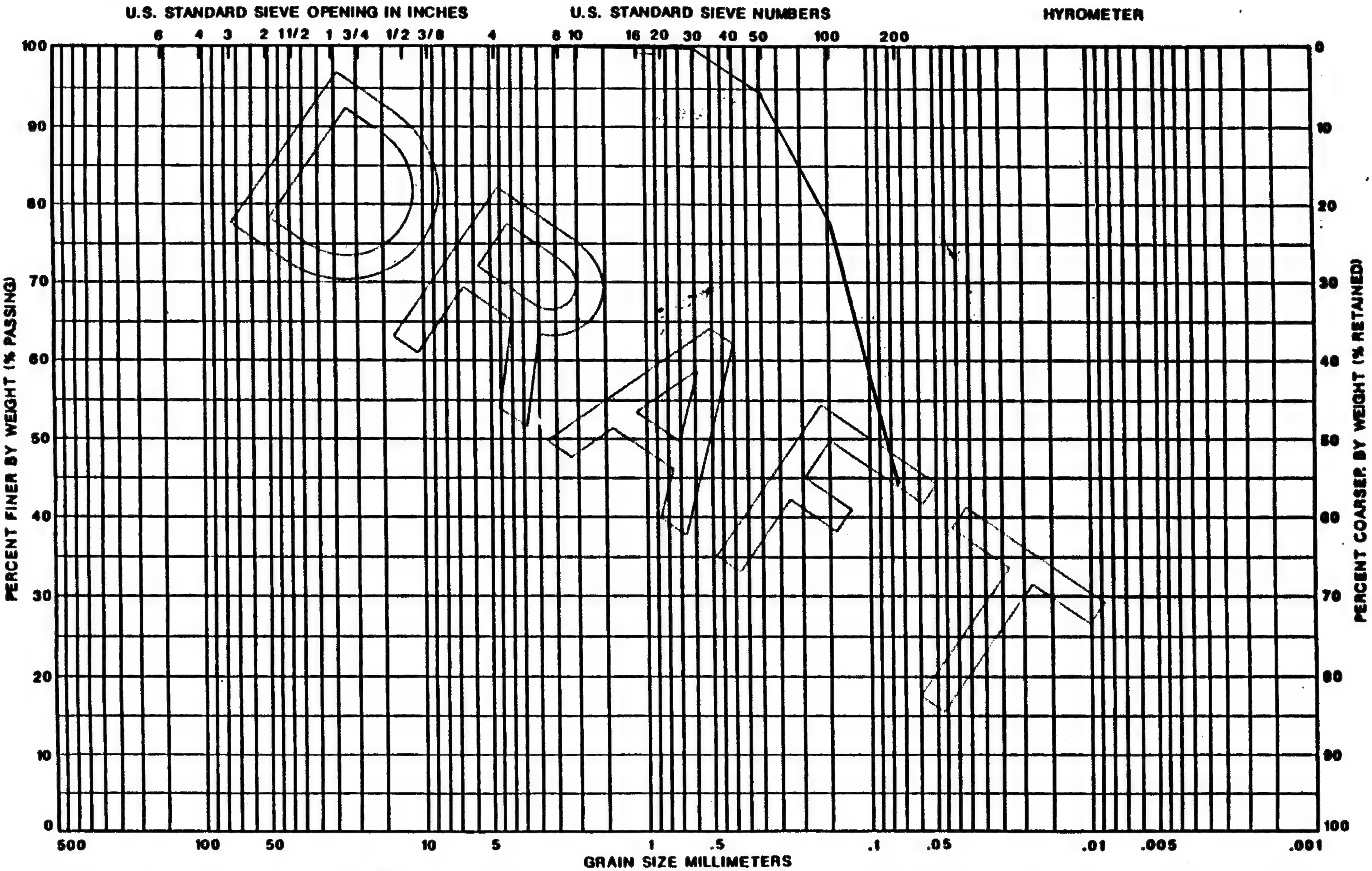
MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0015	10'	SM	SAND WITH SILT	16.7	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

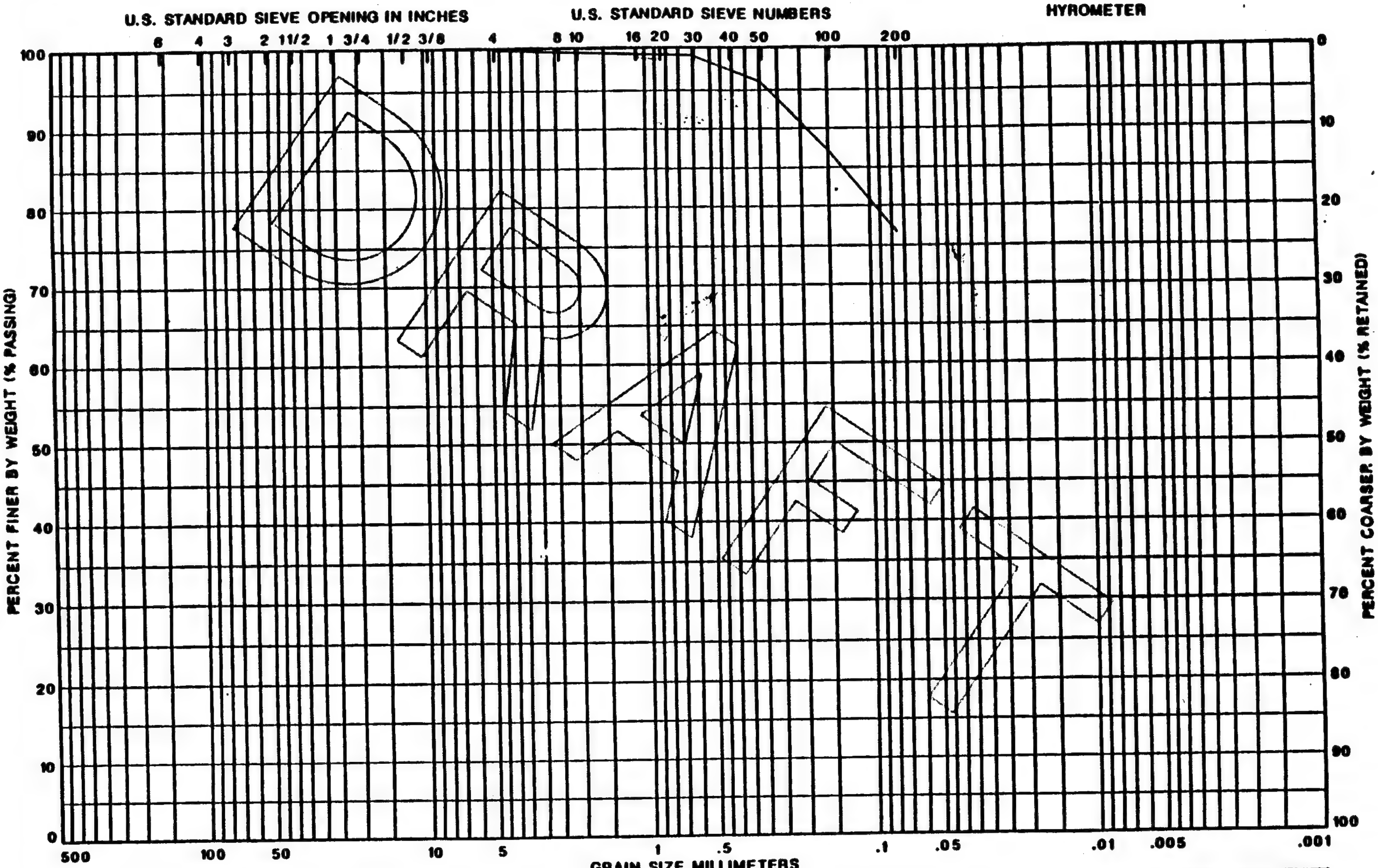


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

PLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT. W	LL	PL	PI
0015	15'	SM	SILTY SAND		N.P.	N.P.	N.P.

Woodward-Clyde Consult

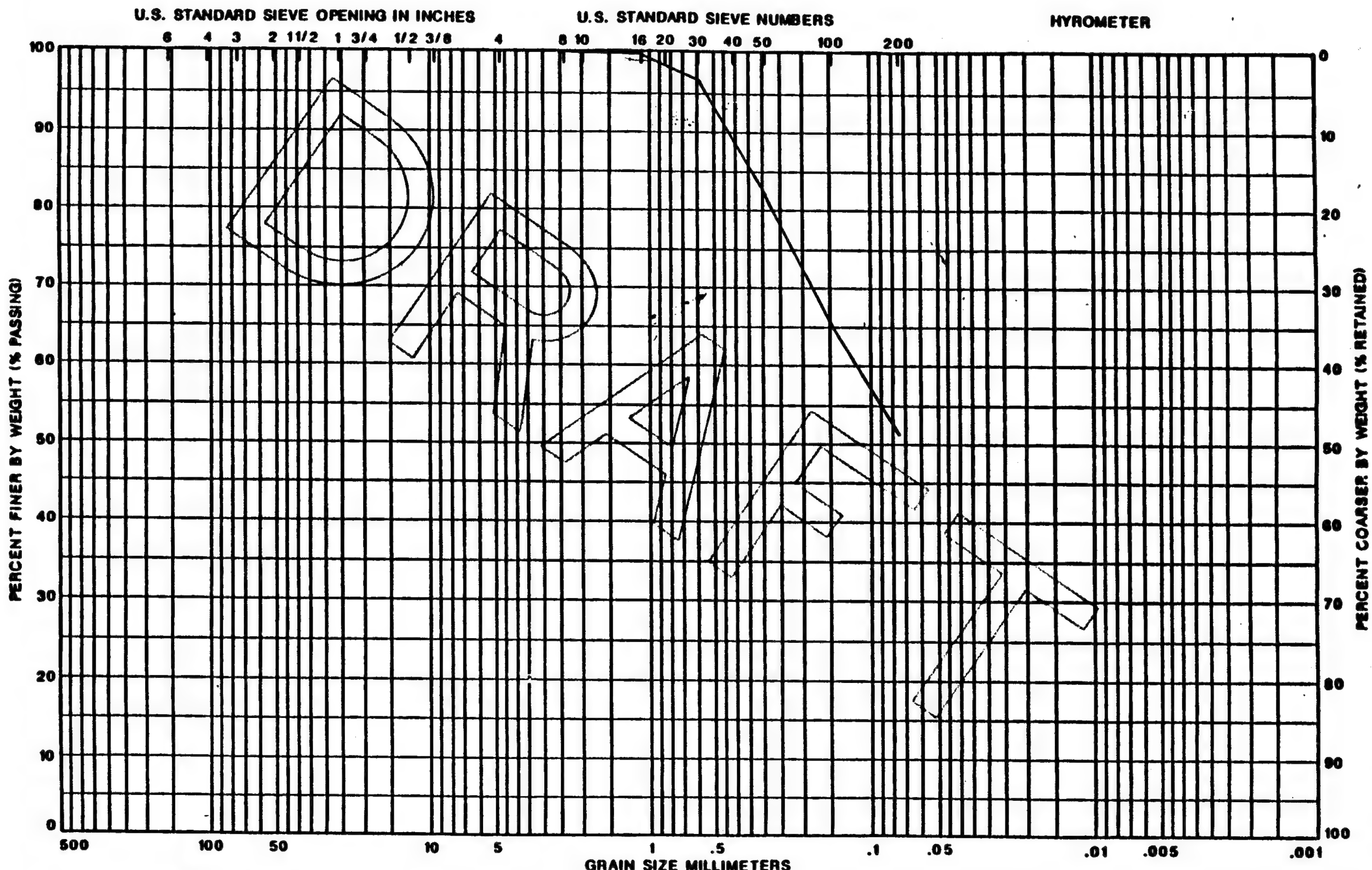
89M



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0015	20'	CL	LEAN CLAY WITH SAND		34	19	15

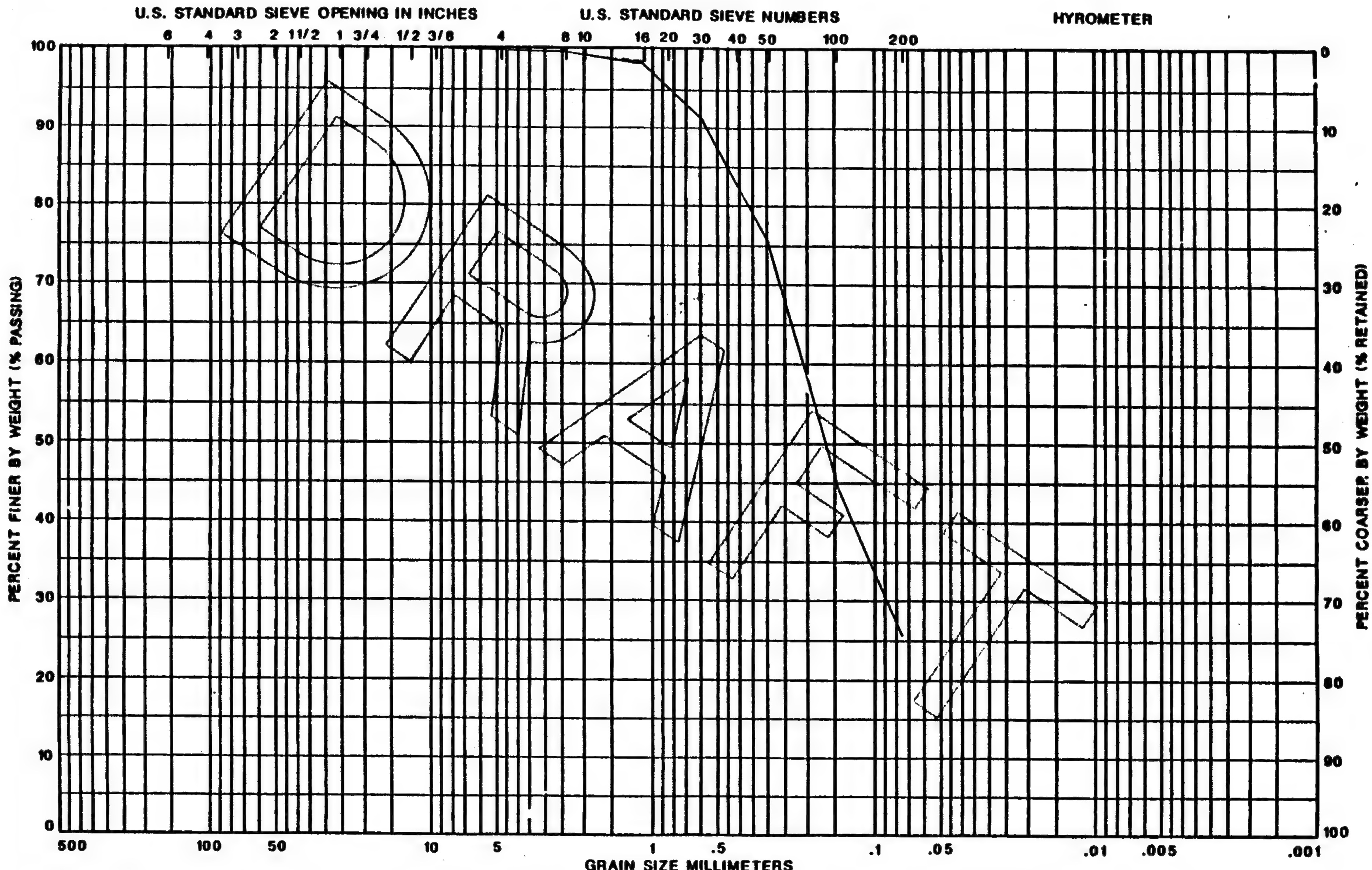
Woodward-Clyde Consultants
89MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
C[illegible]-0015	25'	CL	SANDY LEAN CLAY	[illegible]	42	24	18

Woodward-Clyde Consul[illegible]
891

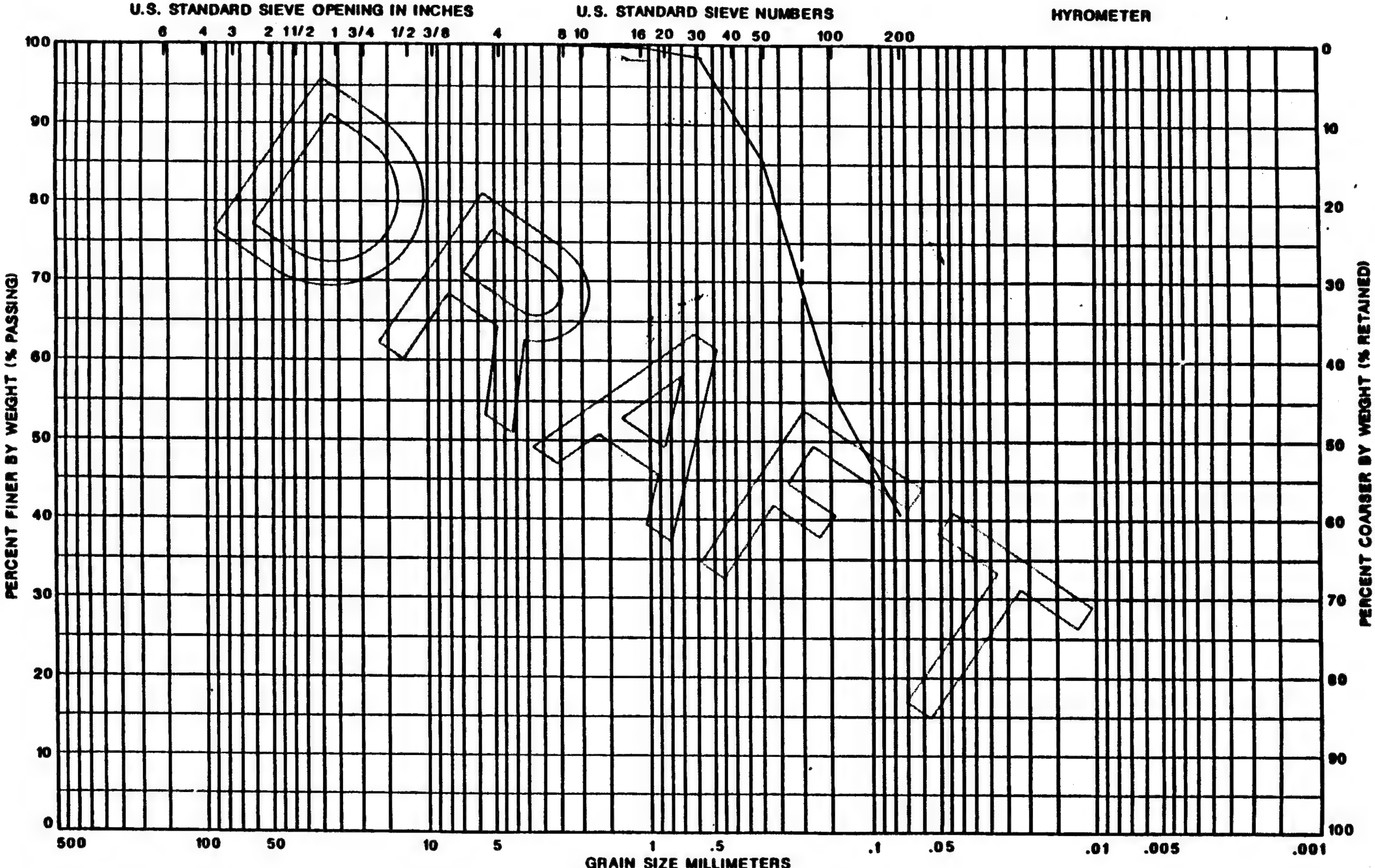


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0017	2.5'-4.0'	SM	SILTY SAND	13.1	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

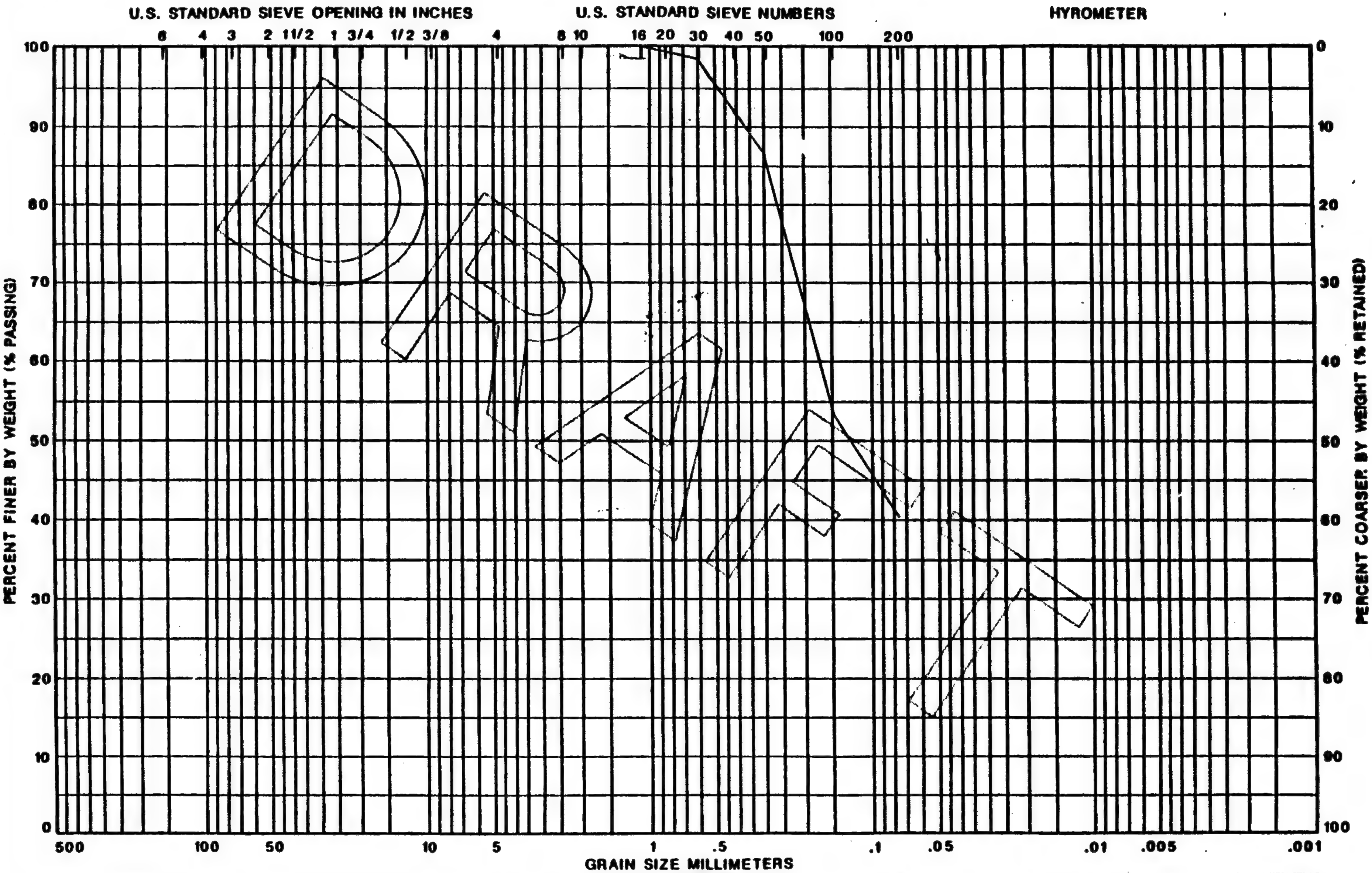
89MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
CO[illegible]B-0017	7.5'	SC	CLAYEY SAND	[illegible].2	23	15	8

Woodward-Clyde Consultants

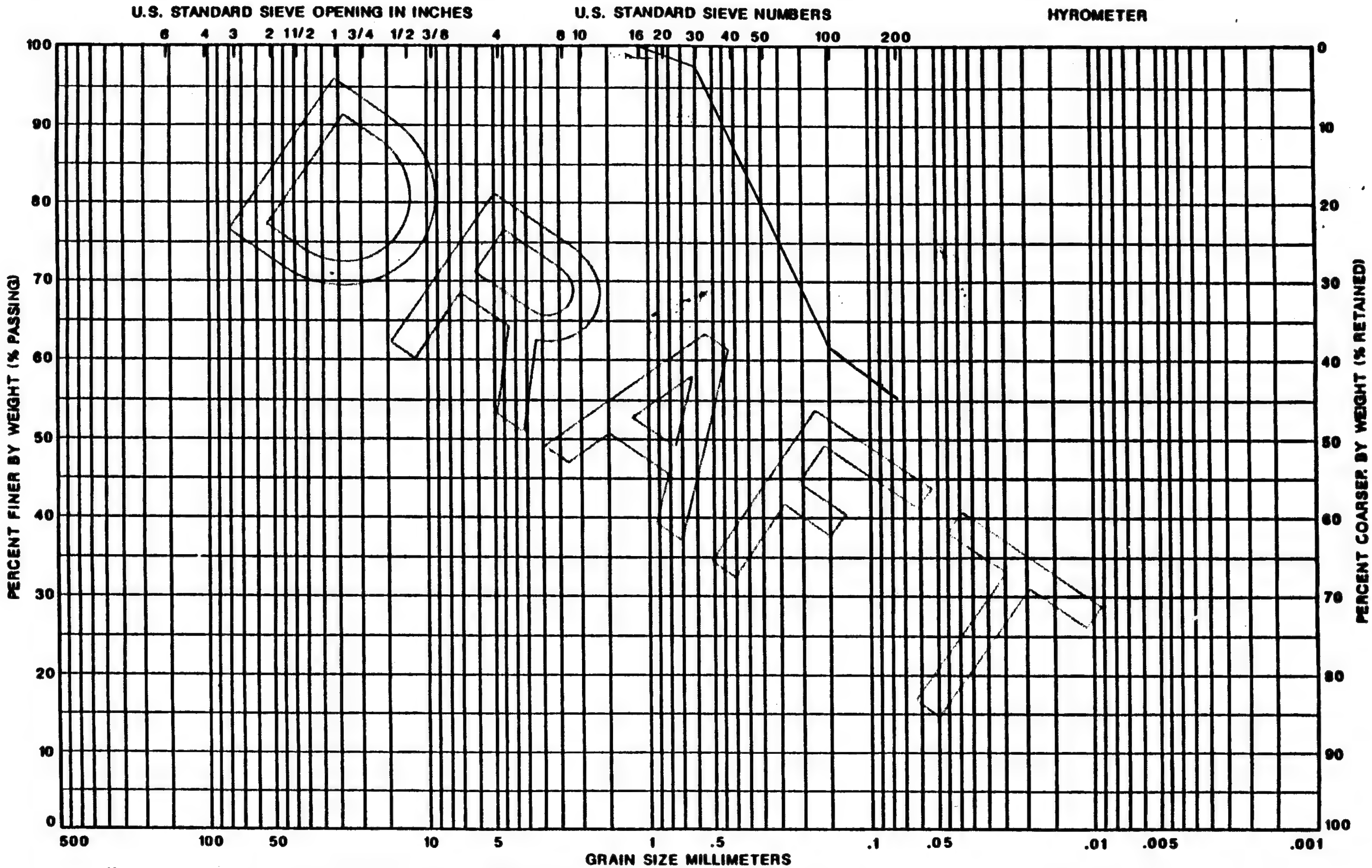


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0017	15.0'-16.5'	SC	CLAYEY SAND	21.2	24	11	13

Woodward-Clyde Consultants

89MC114A

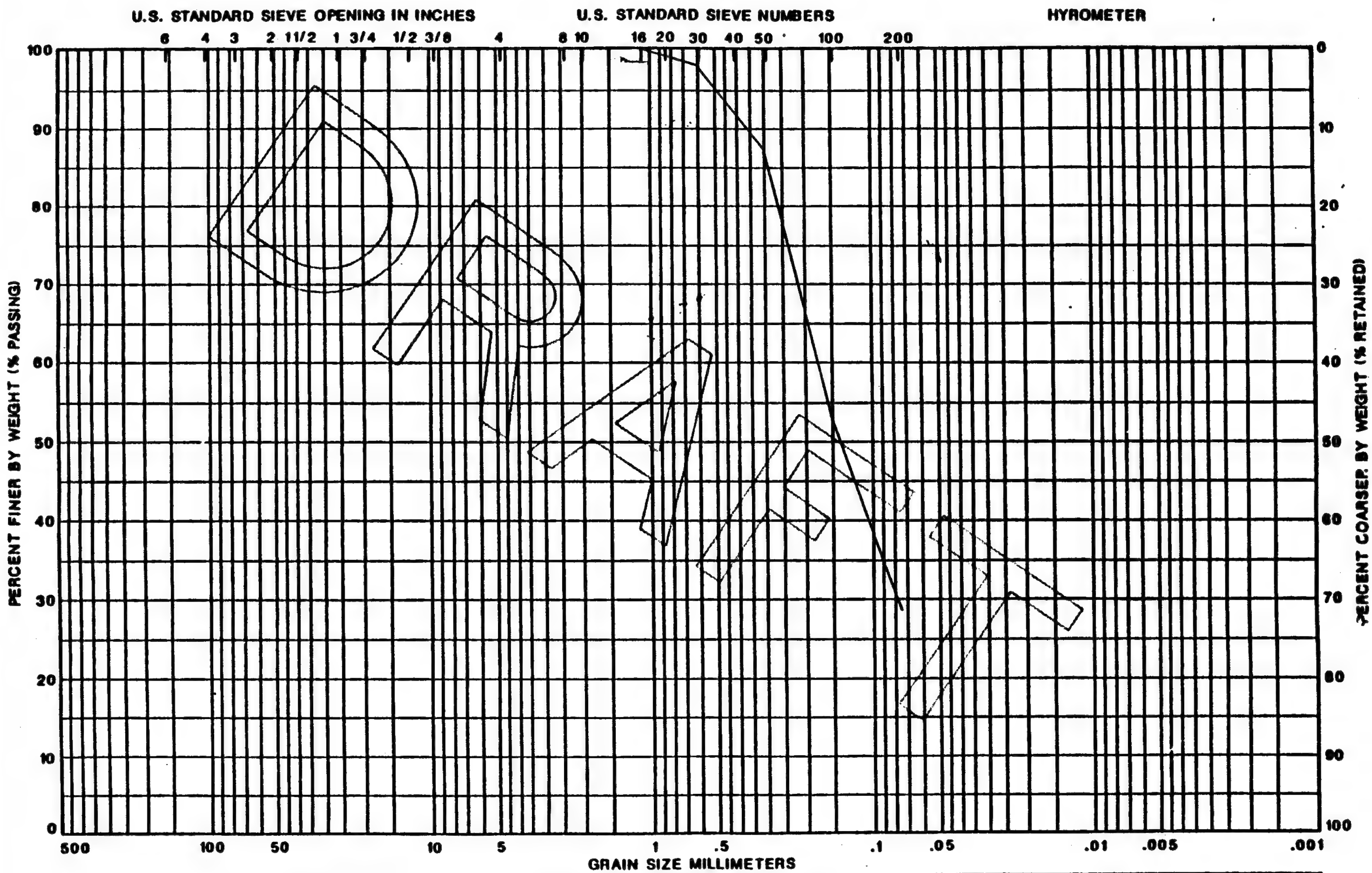


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
[illegible]0017	20'-21.5'	CL	SANDY LEAN CLAY	[illegible]1	38	13	25

Woodward-Clyde Consultants

14A

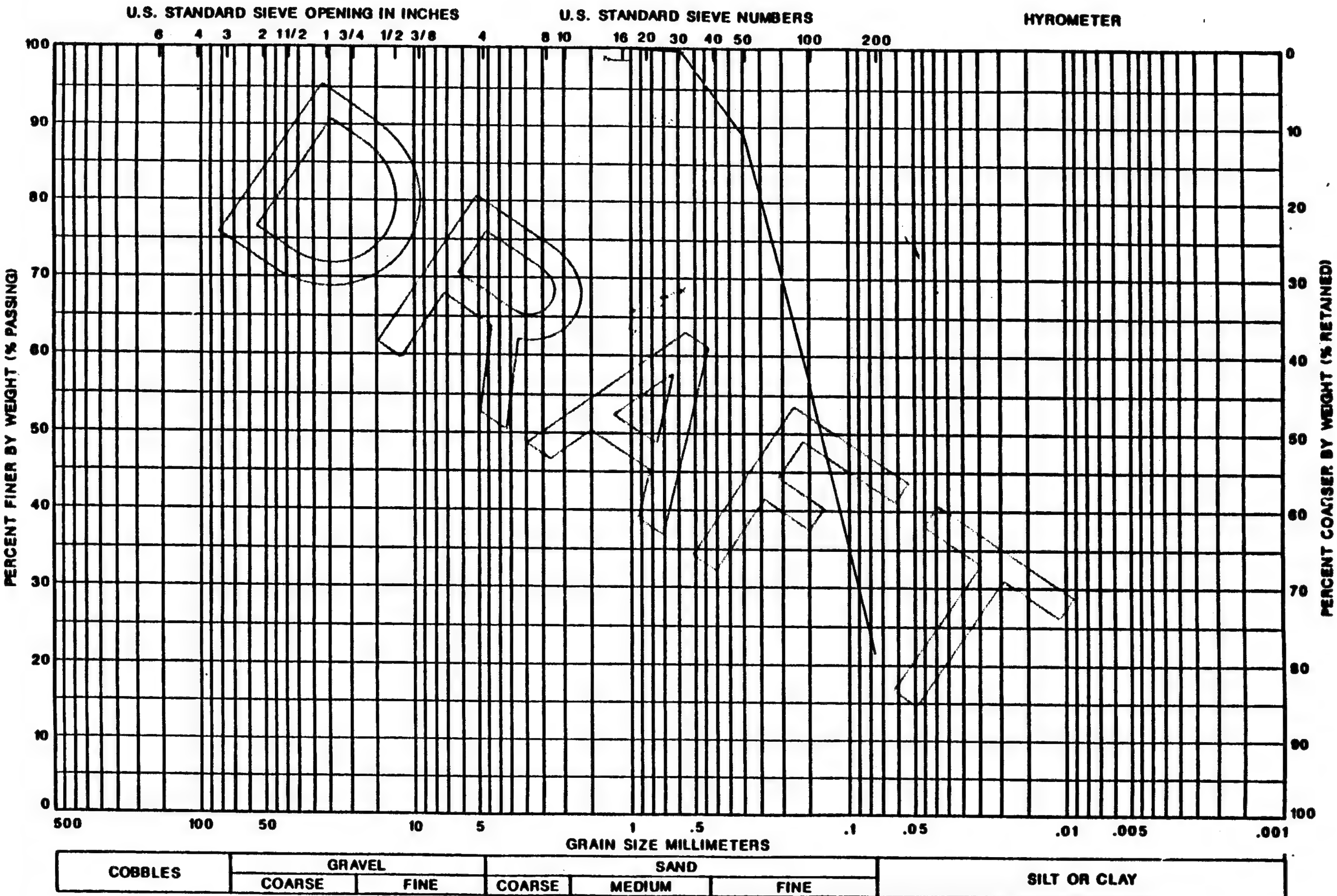


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0022	5'	SM	SILTY SAND	0.4	N.P.	N.P.	N.P.

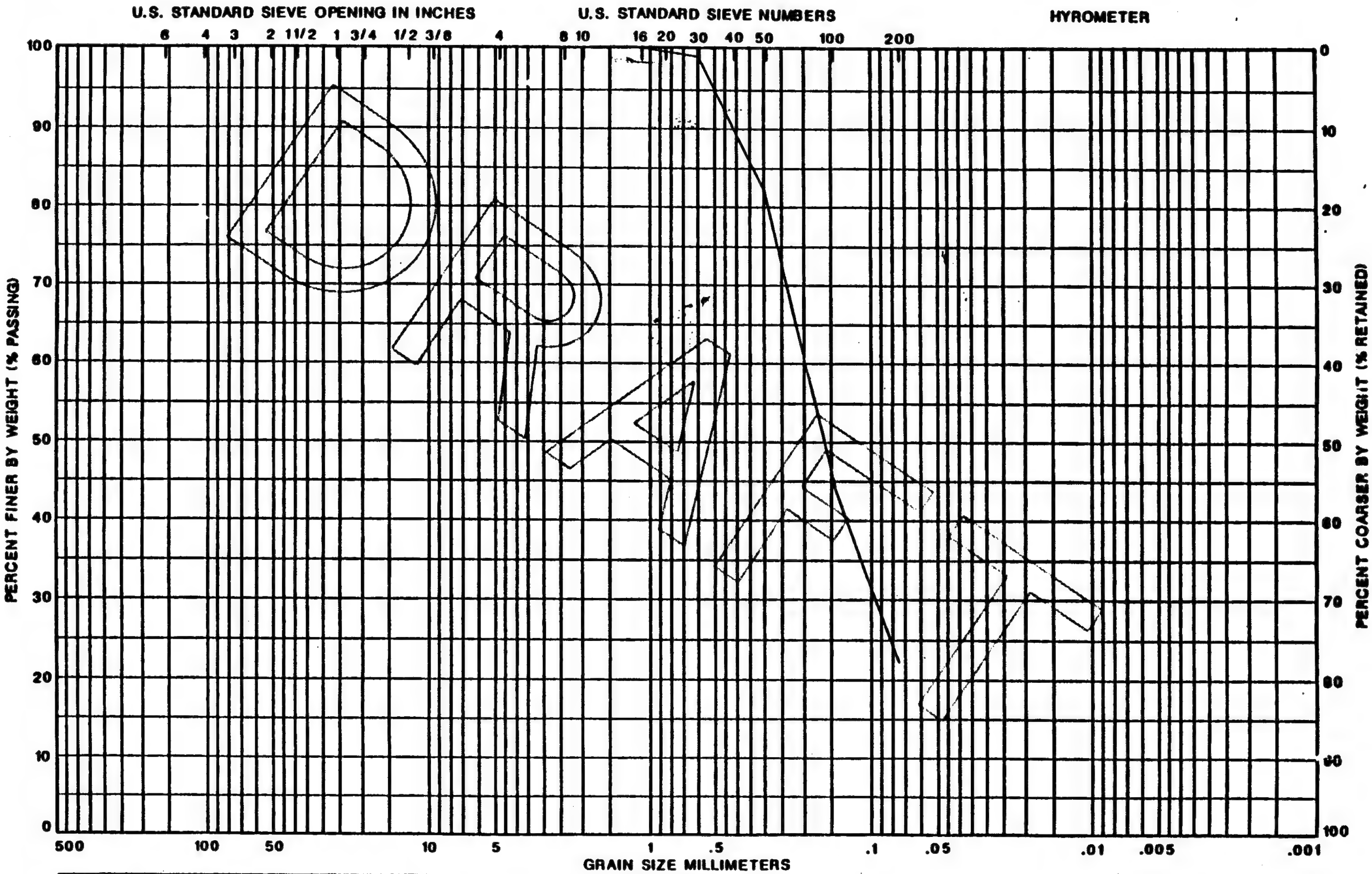
Woodward-Clyde Consultants

89MC114A



SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COF[illegible]-0024	10'	SM	SILTY SAND	[illegible]5	N.P.	N.P.	N.P.

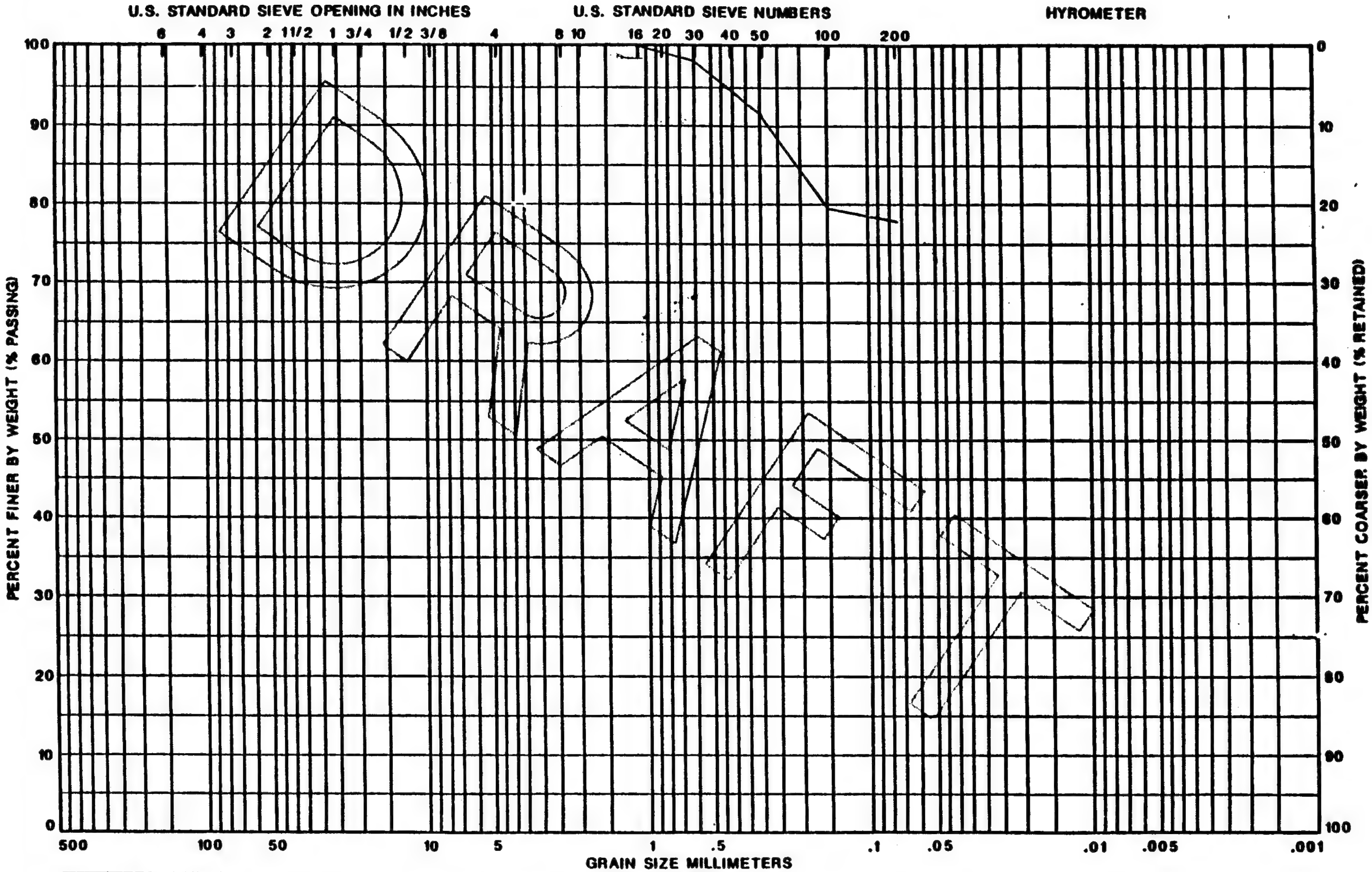
Woodward-Clyde Consult[illegible]



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0024	20'	SM	SILTY SAND	16.3	N.P.	N.P.	N.P.

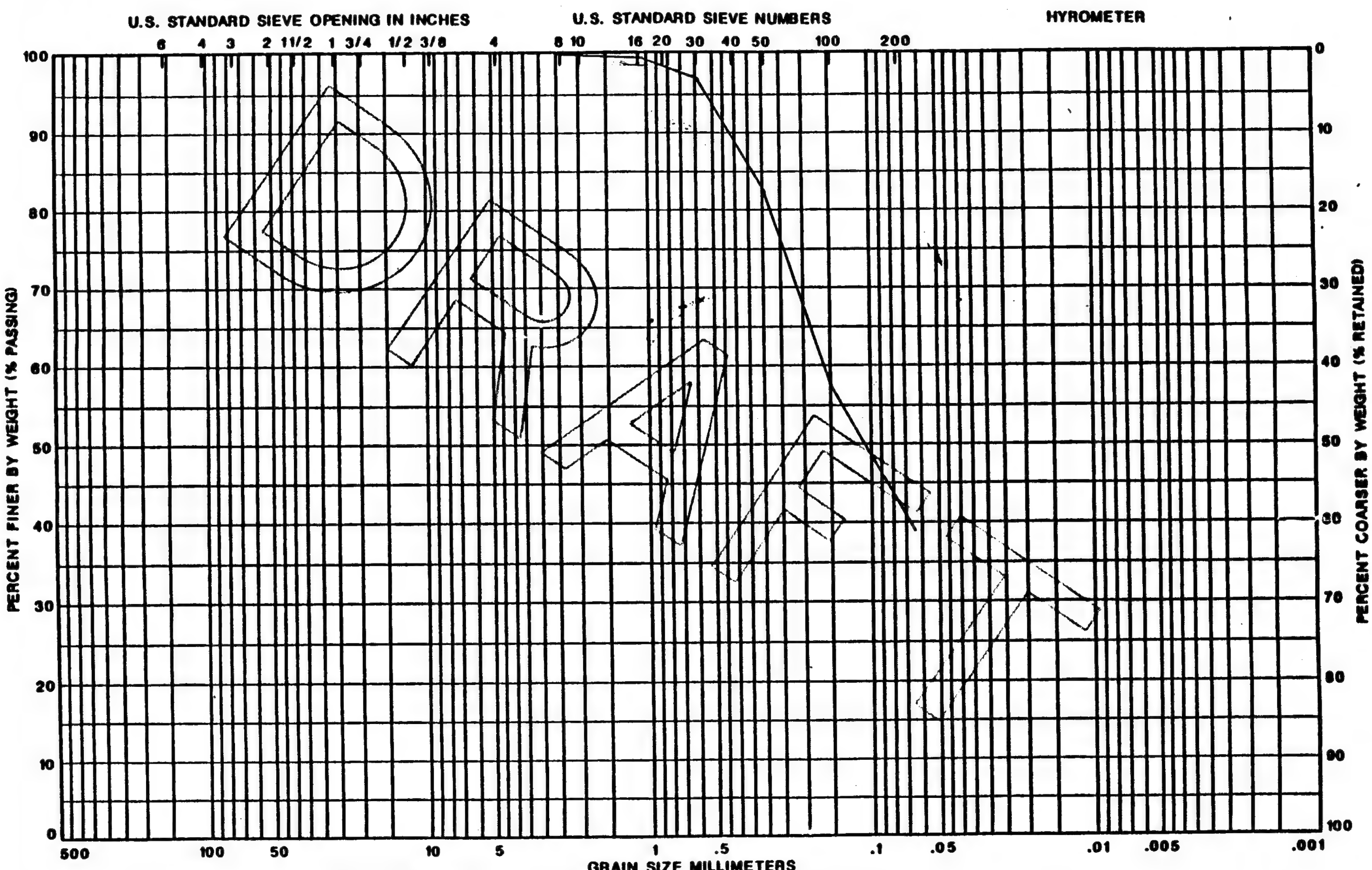
Woodward-Clyde Consultants



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
[illegible]-0025	2.5'-4.0'	ML	SILT	[illegible]	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

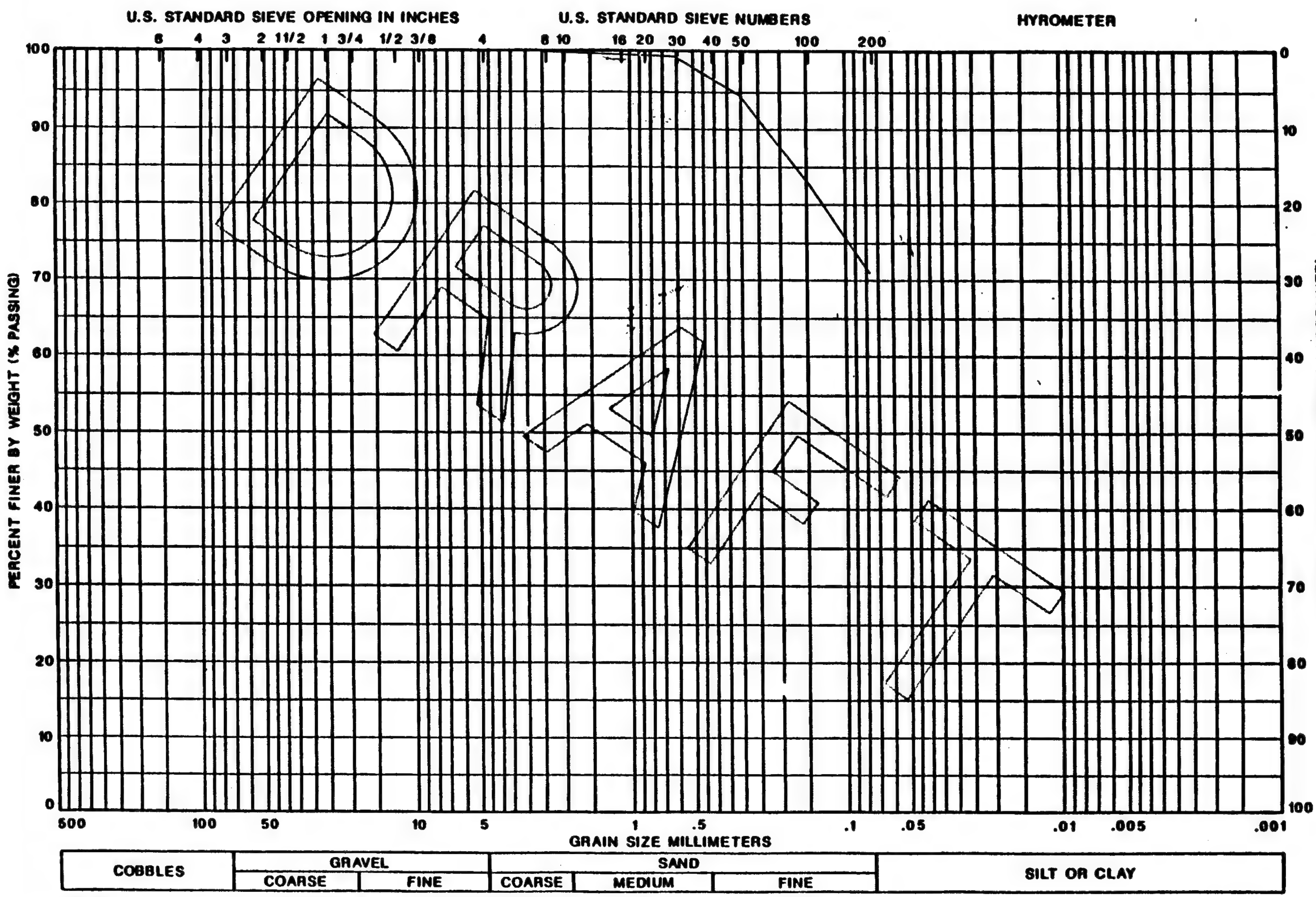


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0025	10'	SC-SM	SILTY, CLAYEY SAND	20.1	23	7	16

Woodward-Clyde Consultants

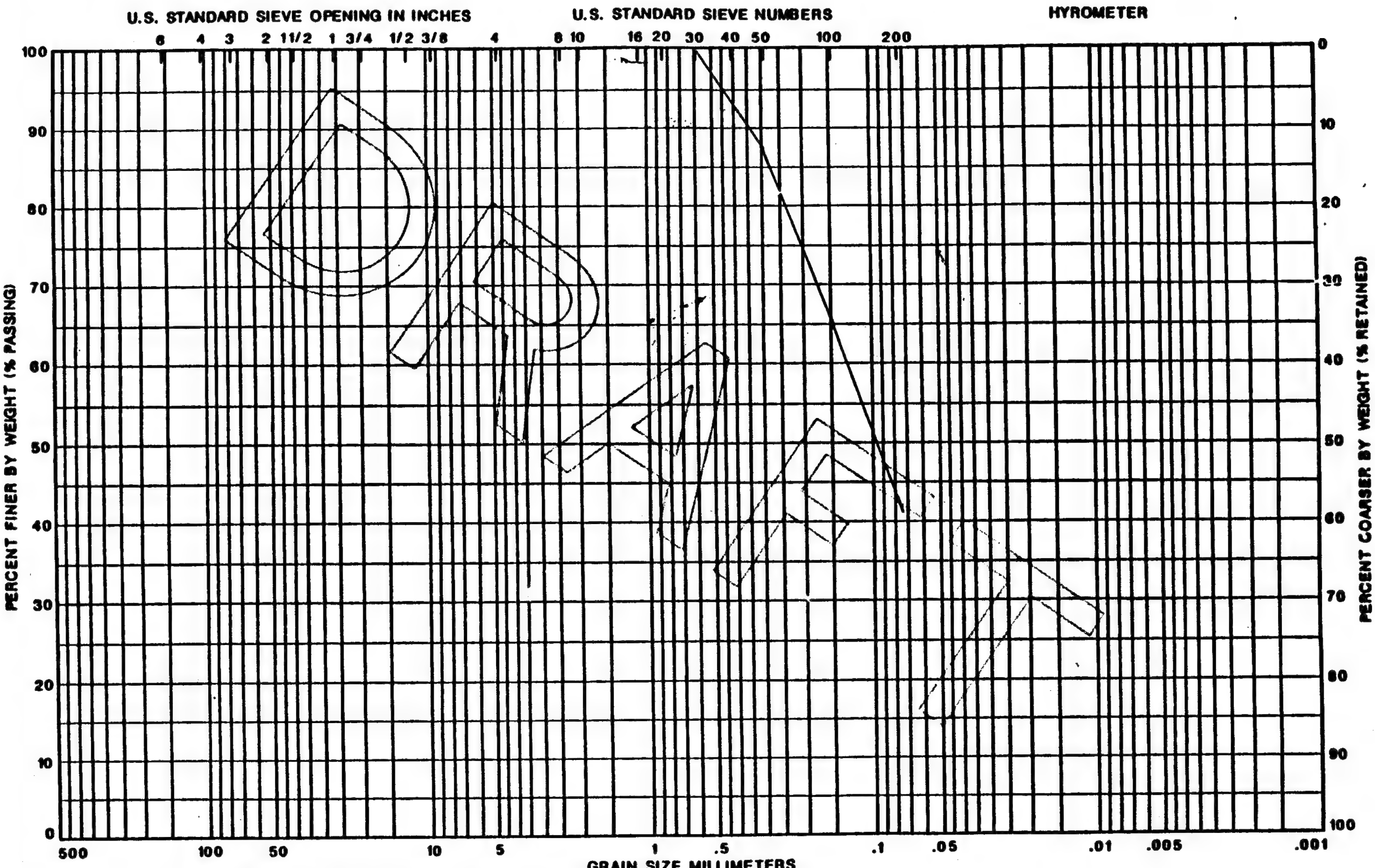
89MC114A



SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
B-0025	20'	CL	LEAN CLAY WITH SAND	2	39	18	21

Woodward-Clyde Consu

14A

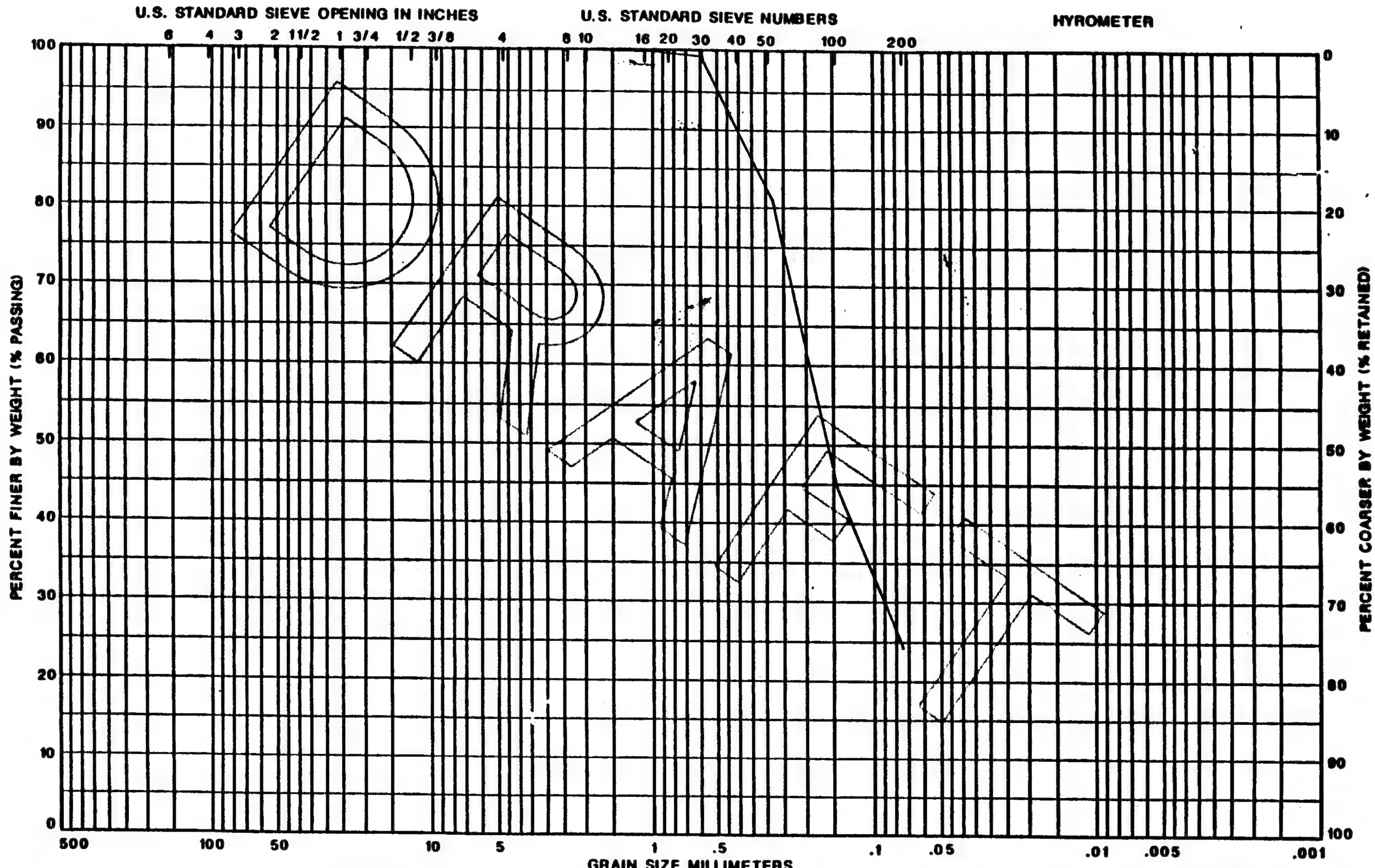


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0026	5'	SM	SILTY SAND	5.8	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

89MC114A

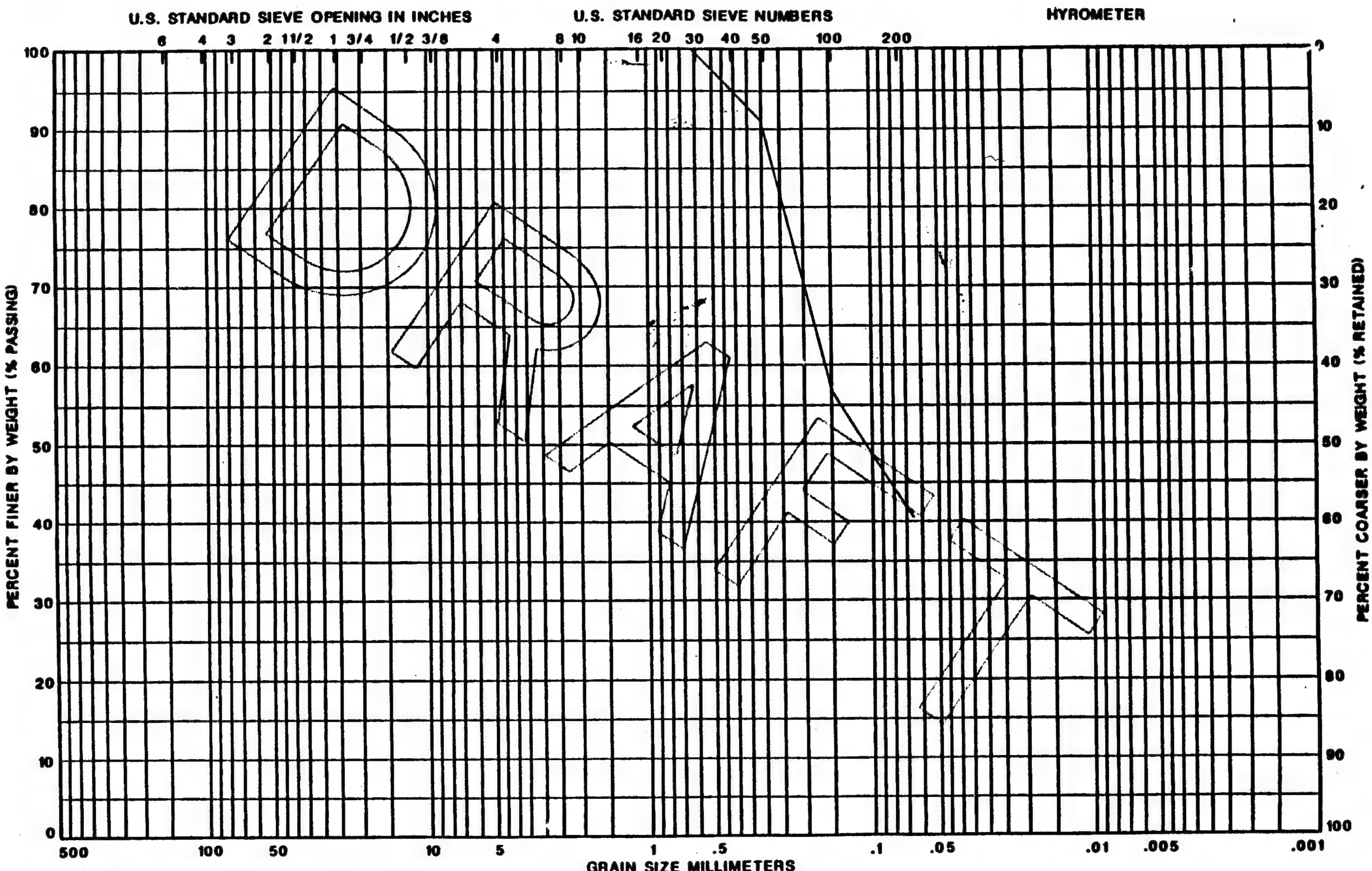


<table>
<tr><td rowspan="2">COBBLES</td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT OR CLAY</td></tr>
<tr><td>COARSE</td><td>FINE</td><td>COARSE</td><td>MEDIUM</td><td>FINE</td></tr>
</table>

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
[redacted]-0028	7.5'	SM	SILTY SAND	[redacted]6	N.P.	N.P.	N.P.

COE[redacted]

Woodward-Clyde Consult[redacted]

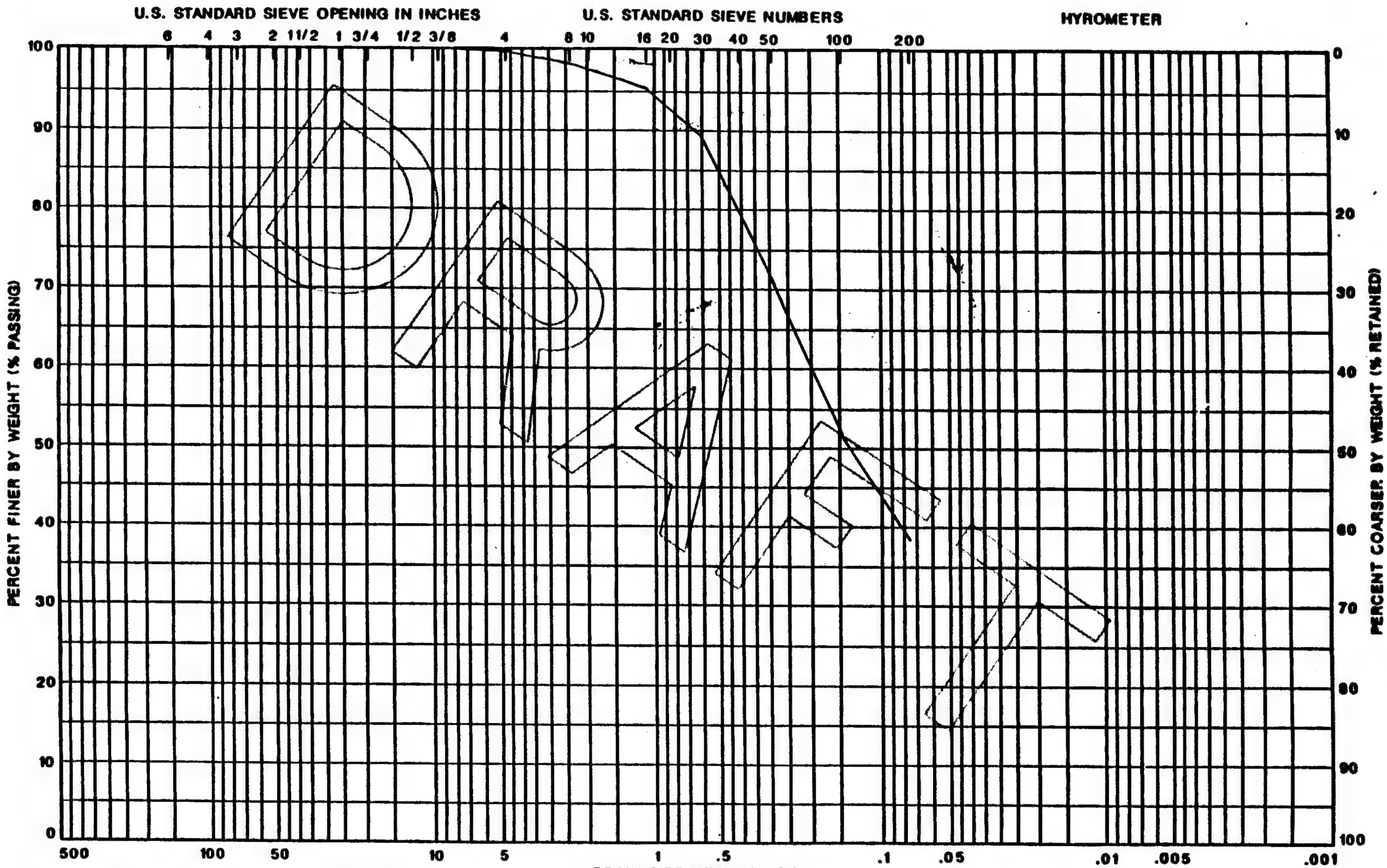


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0029	7.5'	SC	CLAYEY SAND	19.5	25	11	13

Woodward-Clyde Consultants

89MC114A

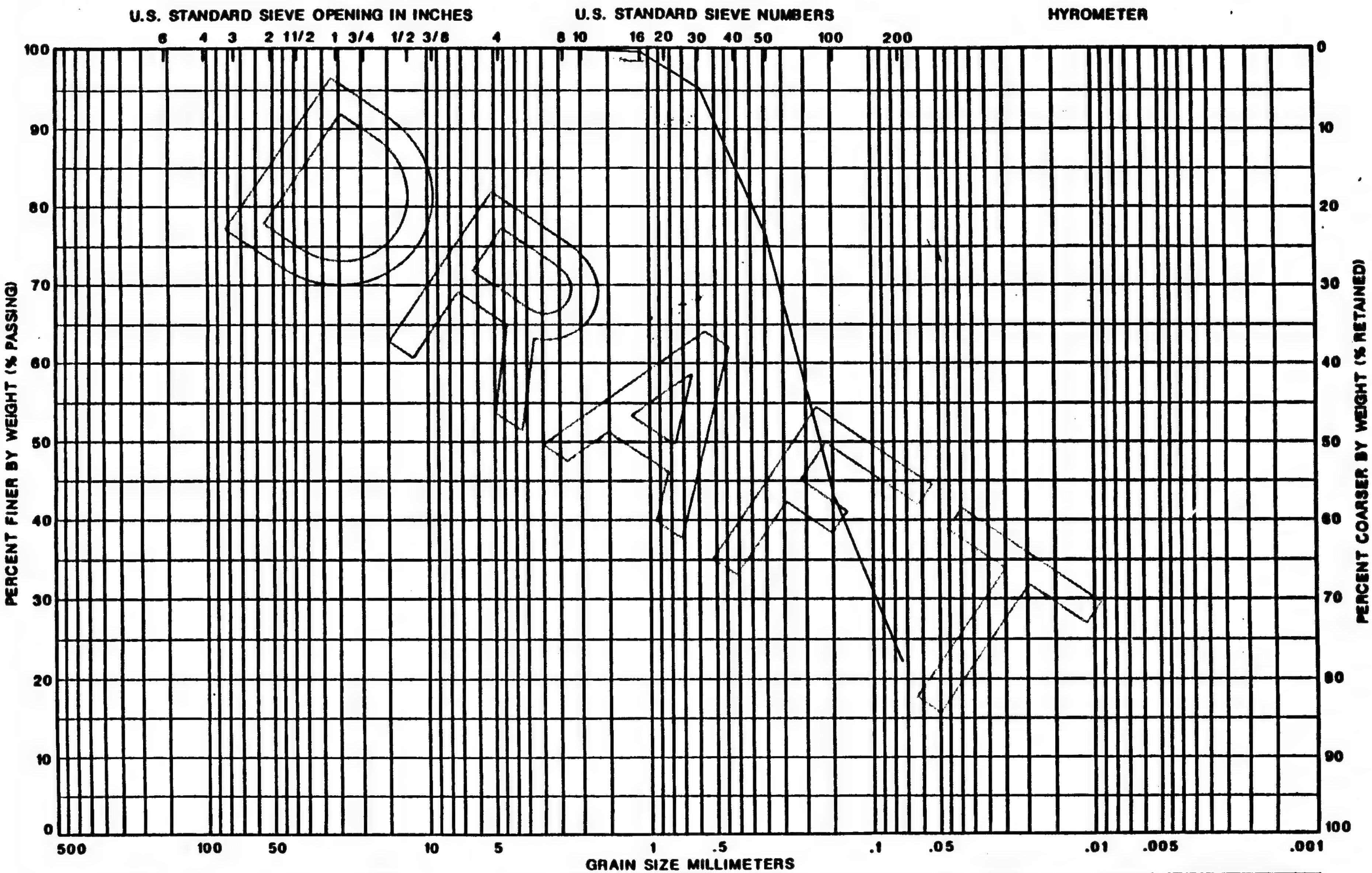


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
CO B-0029	20'	SC	CLAYEY SAND	.8	47	20	27

Woodward-Clyde Consult

114A

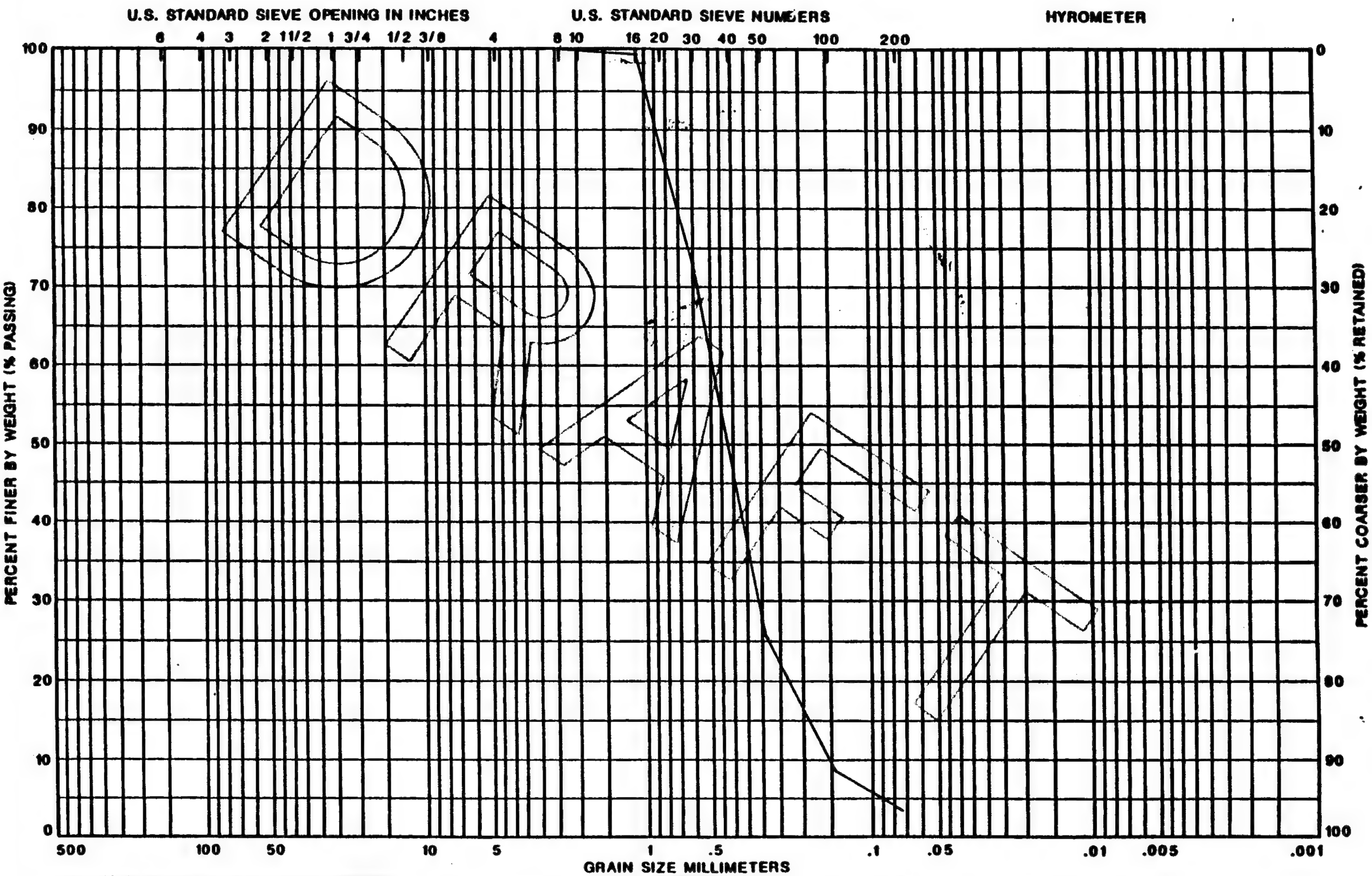


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0031	2.5'	CL-ML	SILTY CLAY WITH SAND	8.0	22	15	7

Woodward-Clyde Consultants

89MC114A

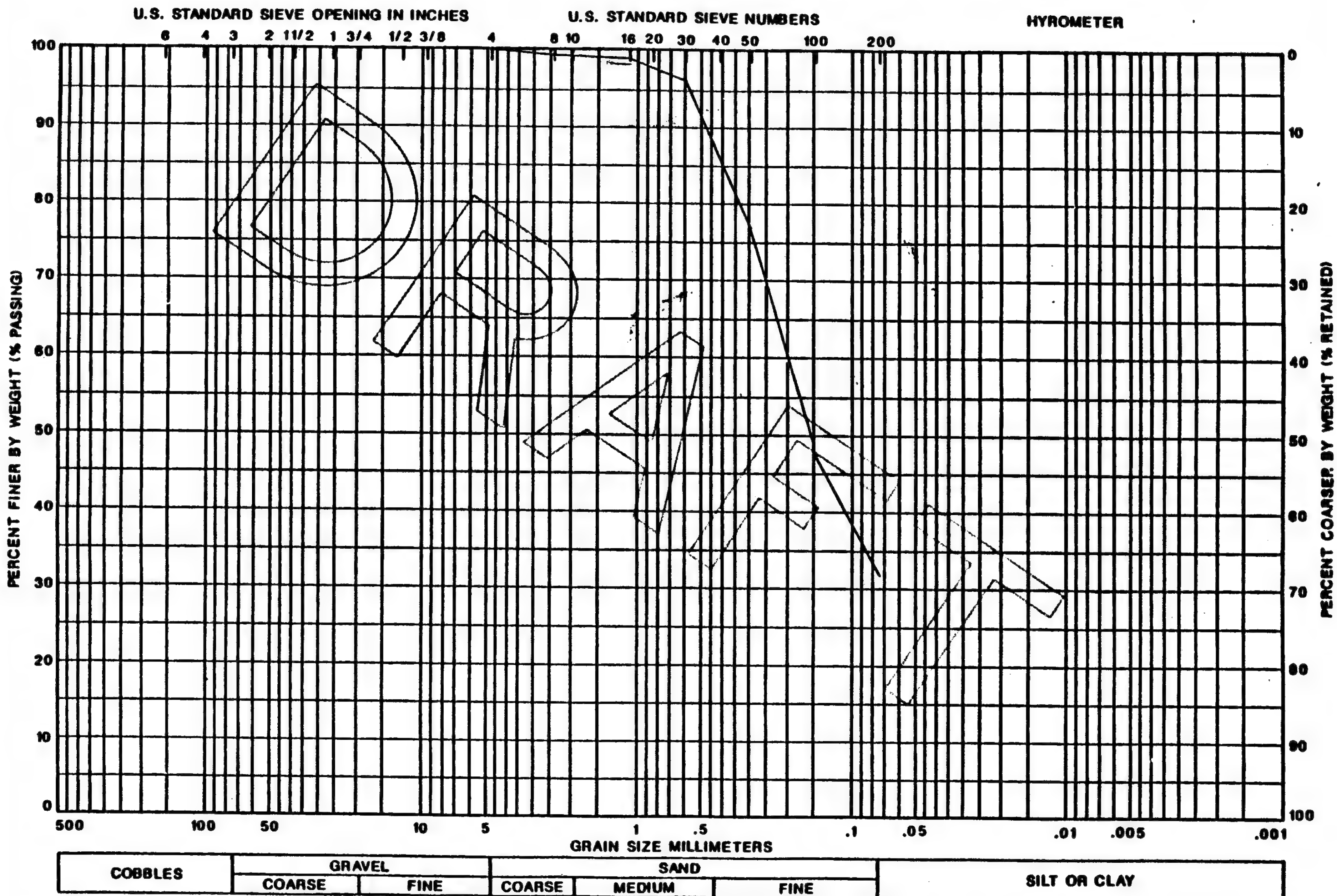


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
[illegible]-0033	2.5'	SP	POORLY GRADED SAND	[illegible]6	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

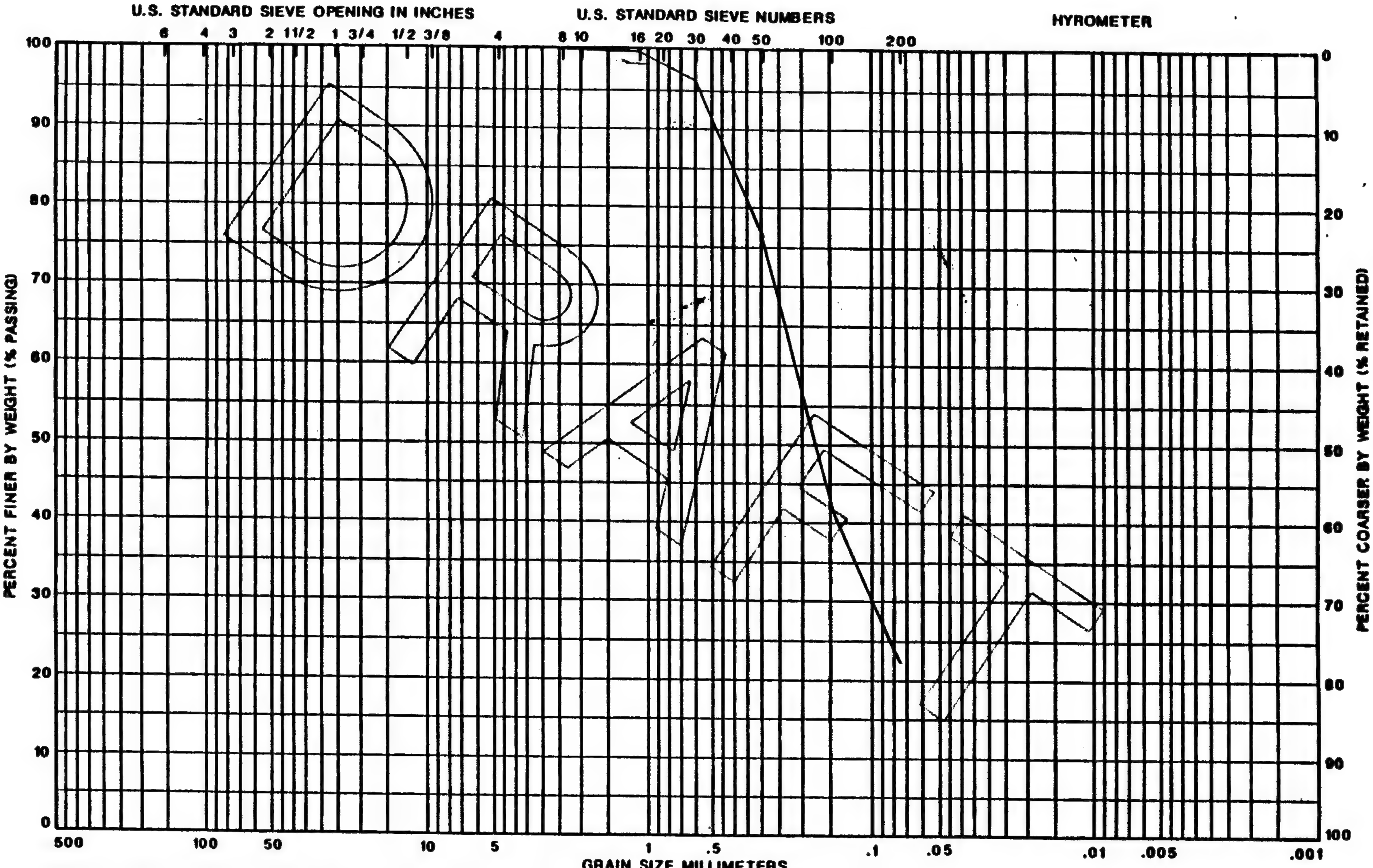
114A



	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0034	2.5'	SM	SILTY SAND		N.P.	N.P.	N.P.

Woodward-Clyde Consultants

89MC114A

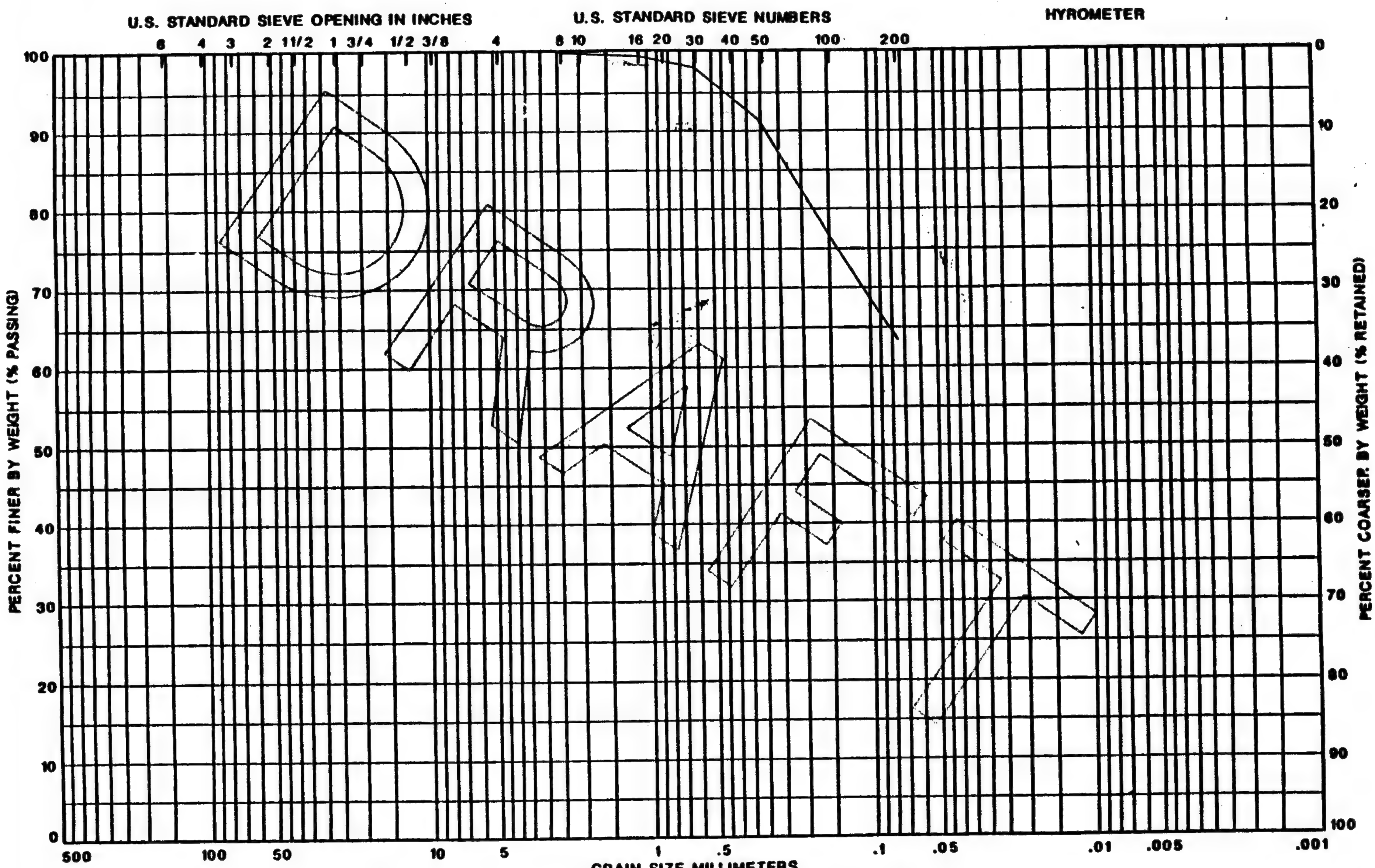


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

COF

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
0034	7.5'	SM	SILTY SAND		N.P.	N.P.	N.P.

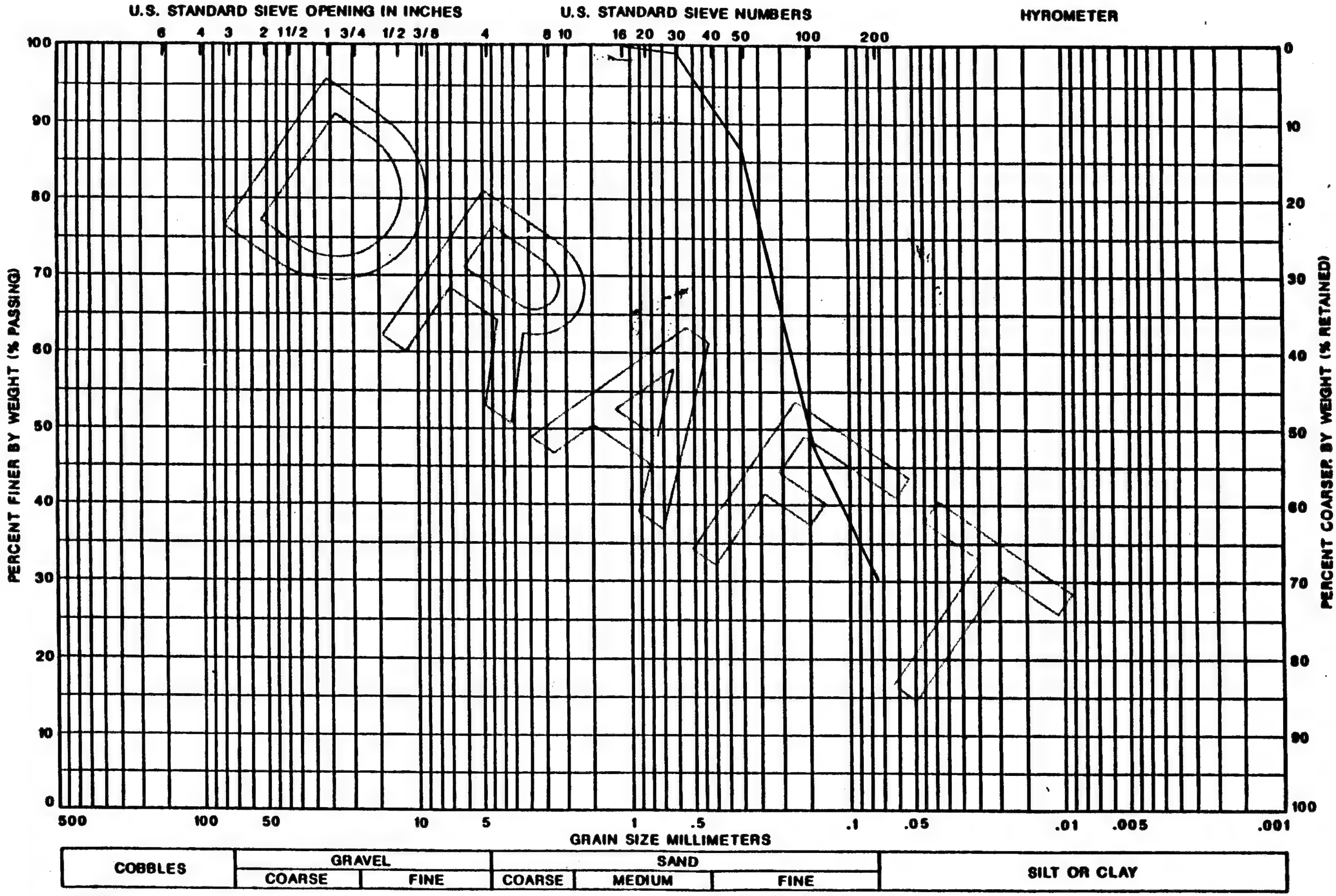
Woodward-Clyde Consult
89M



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0034	15'	CL	SANDY LEAN CLAY		31	17	14

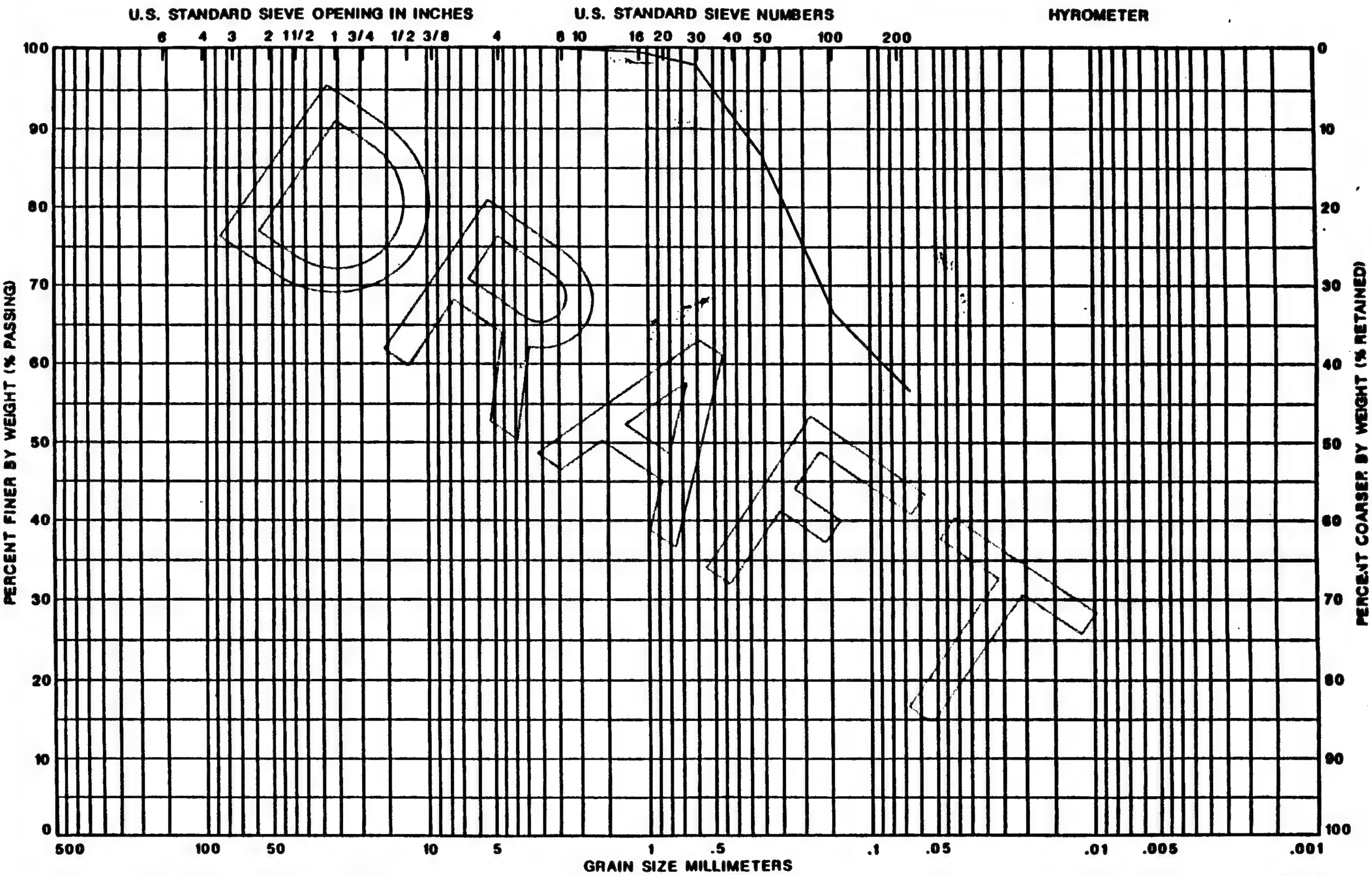
Woodward-Clyde Consultants
89MC114A



SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COF 0034	20'	SM	SILTY SAND		N.P.	N.P.	N.P.

Woodward-Clyde Consultants

89N

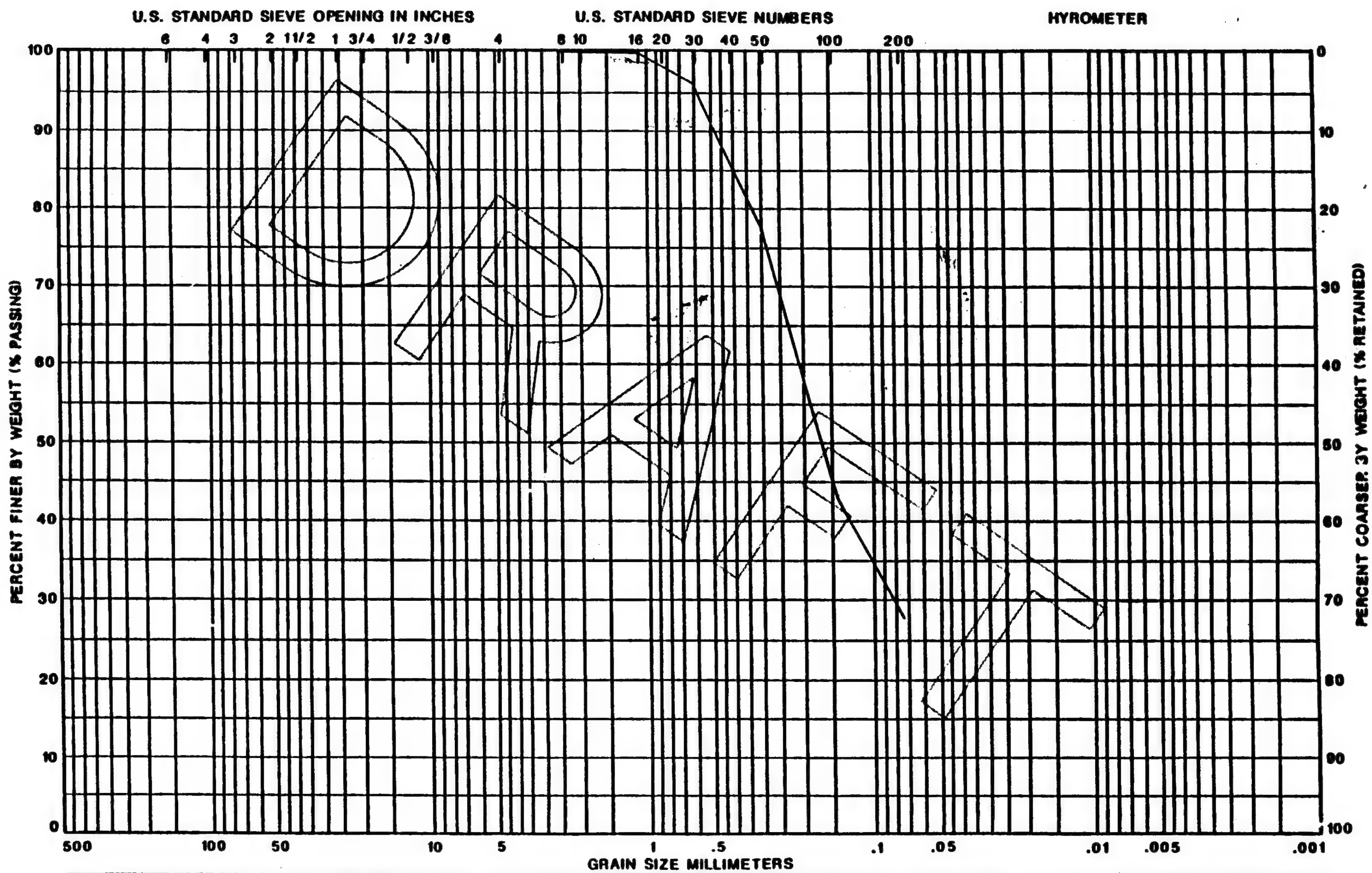


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0034	25'	CL	SANDY LEAN CLAY		46	19	27

Woodward-Clyde Consultants

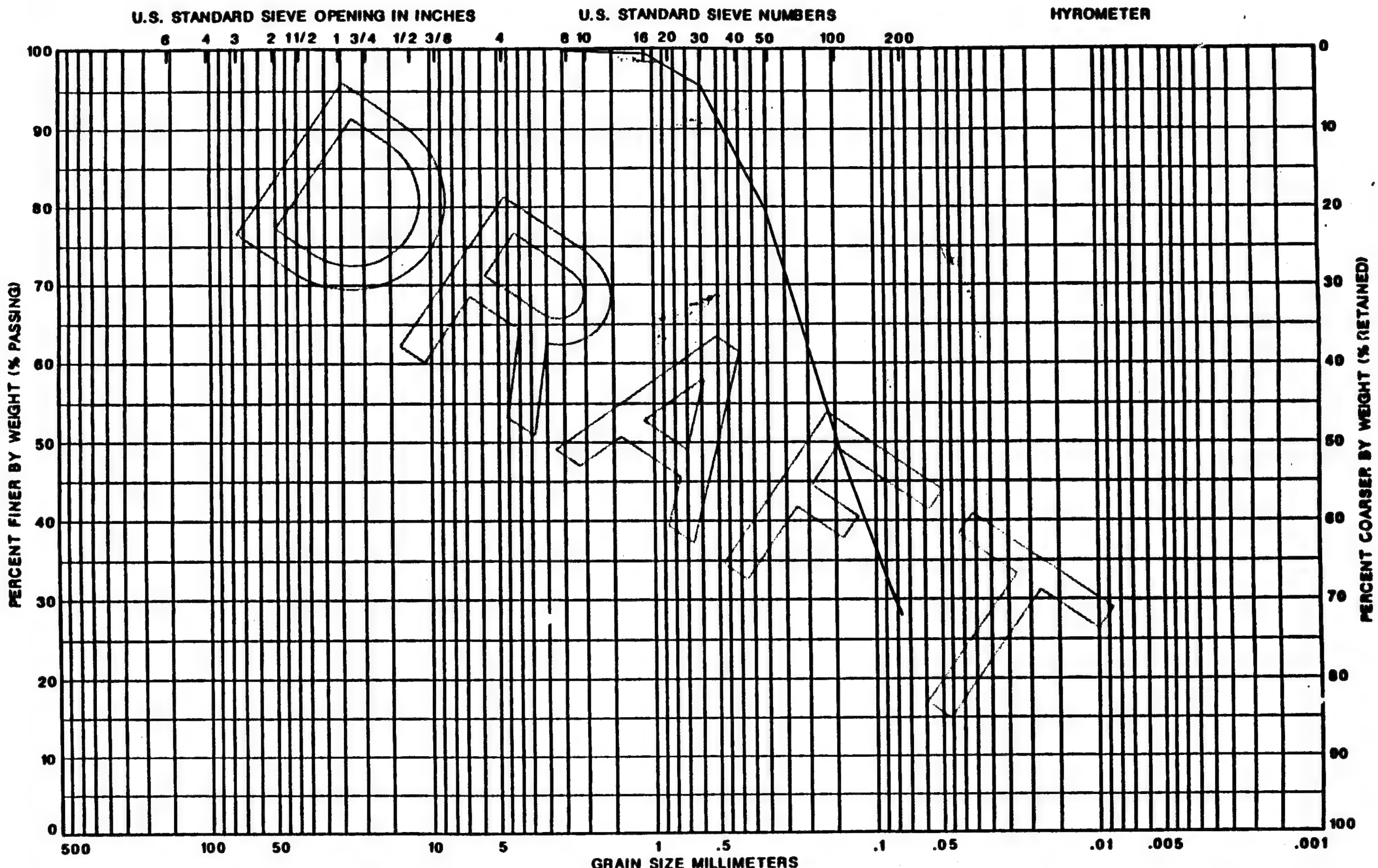
89MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
C[illegible]-0035	2.5'	CL	LEAN CLAY WITH SAND	[illegible]	26	18	8

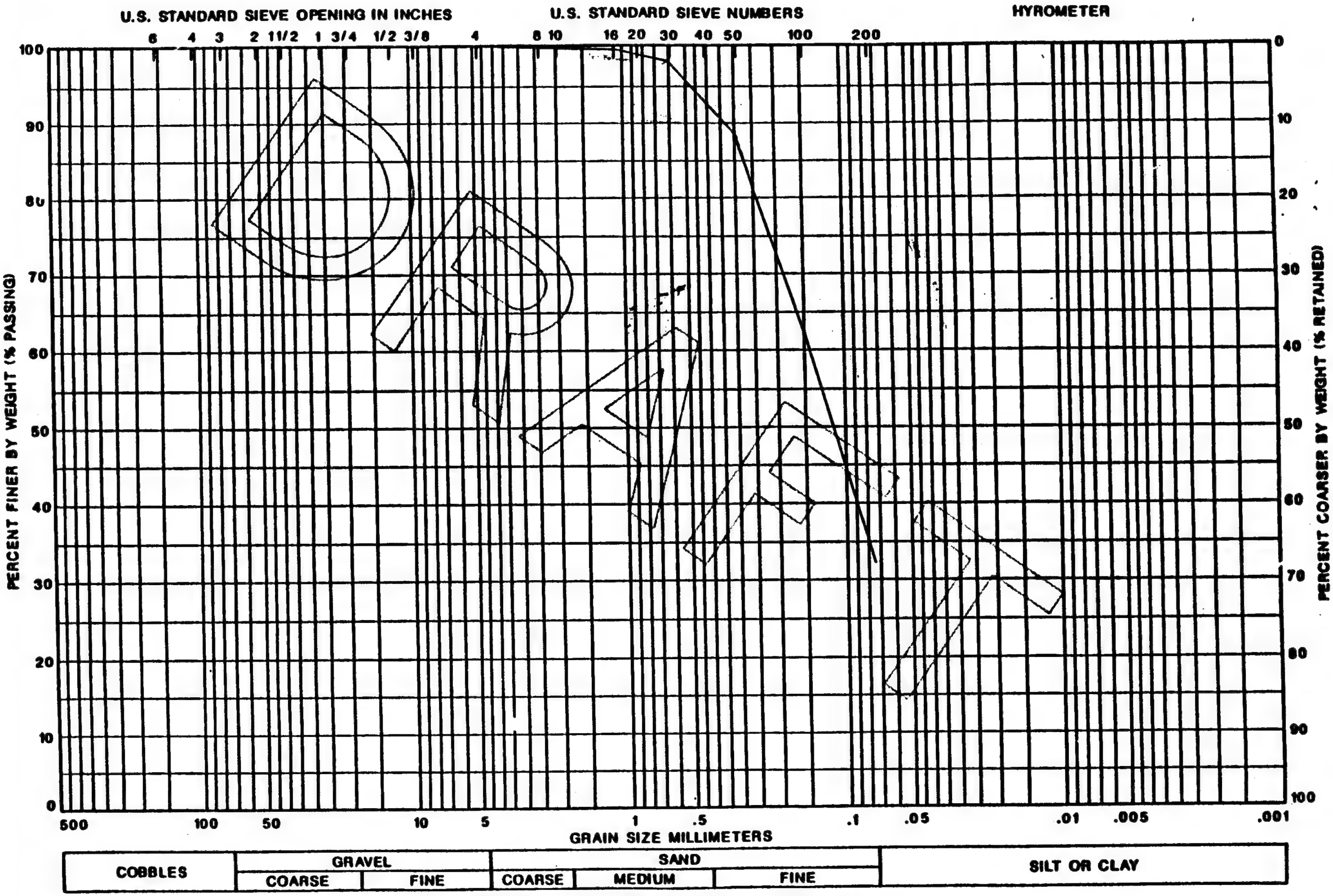
Woodward-Clyde Consult[illegible]
89[illegible]



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

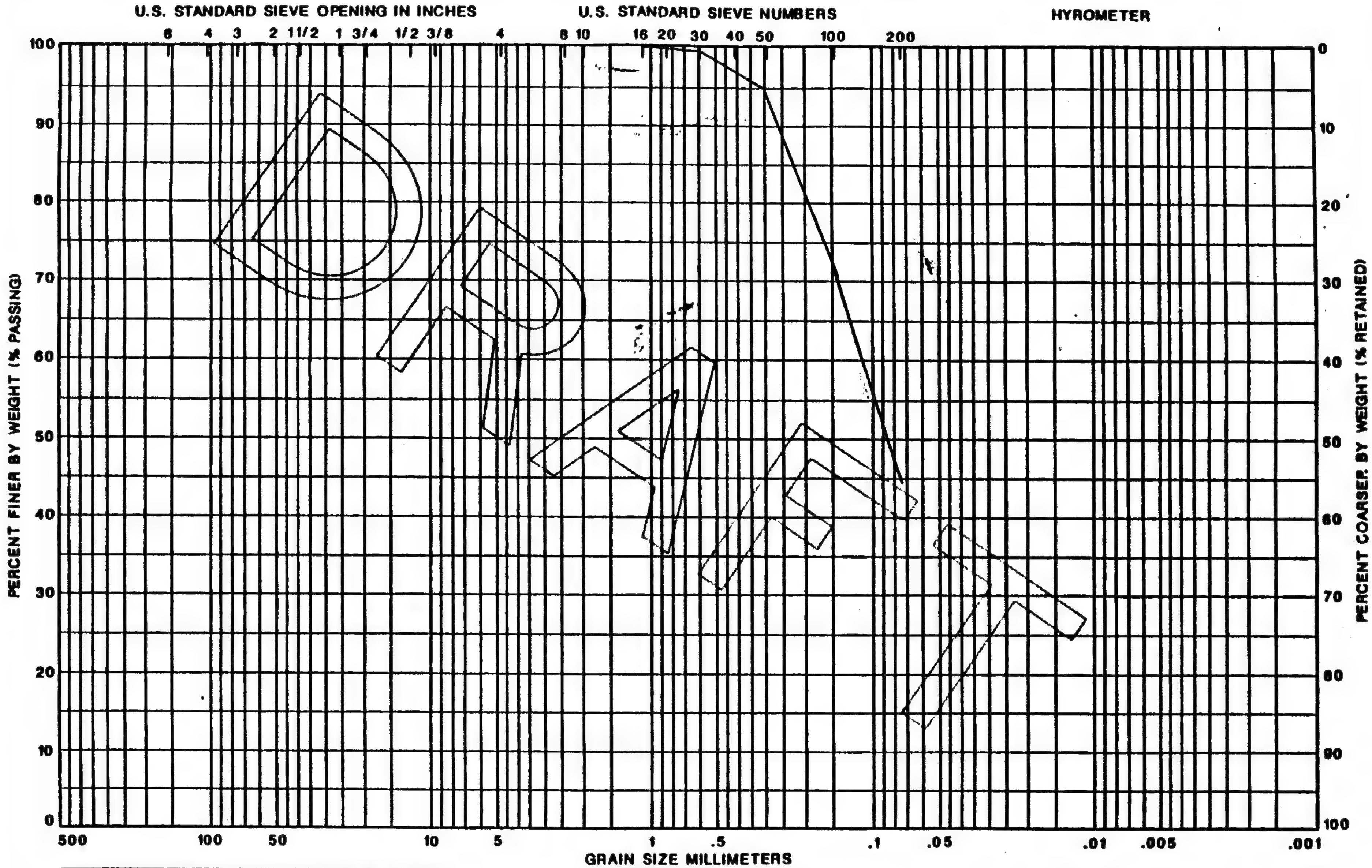
	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0035	7'	SM	SILTY SAND		N.P.	N.P.	N.P.

Woodward-Clyde Consultants
89MC114A



SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
B-0035	14'	SM	SILTY SAND		N.P.	N.P.	N.P.

Woodward-Clyde Consultants

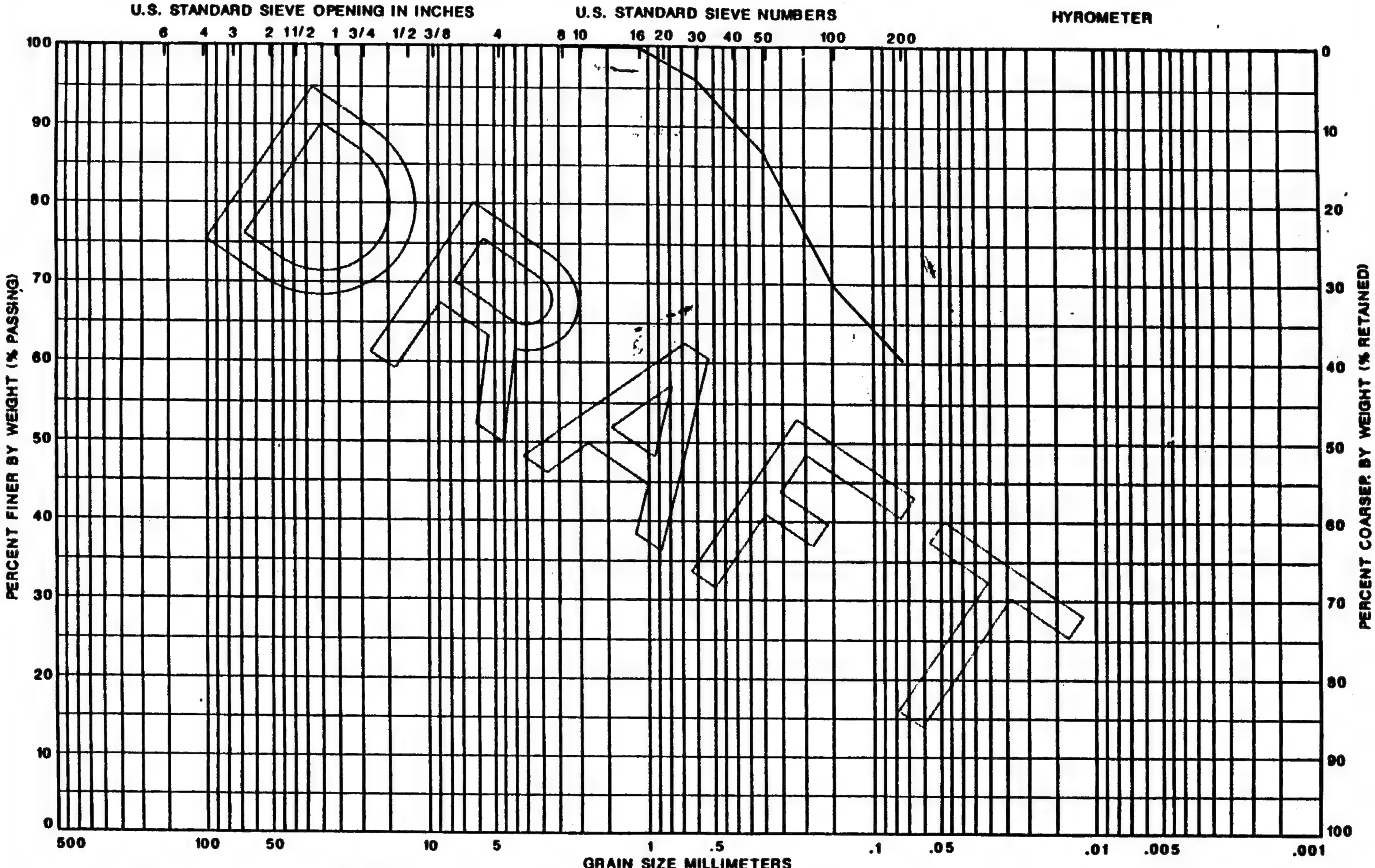


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COEL	SB-0035	19'	SM	SILTY SAND		N.P.	N.P.	N.P.

Woodward-Clyde Consultants

89MC114A

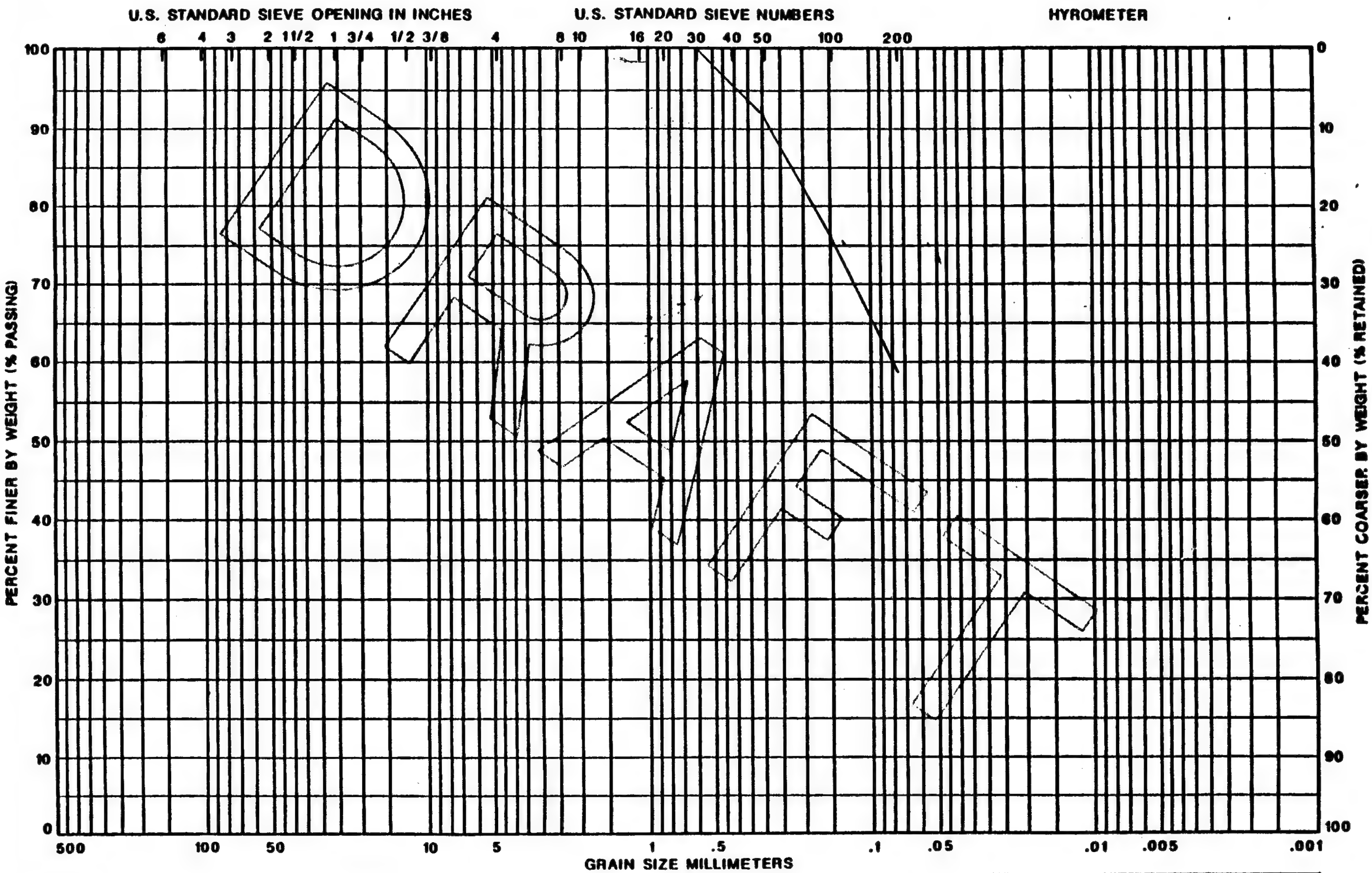


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
COF SB-0035	24'	CH	SANDY FAT CLAY		50	23	27

Woodward-Clyde Consultants

8

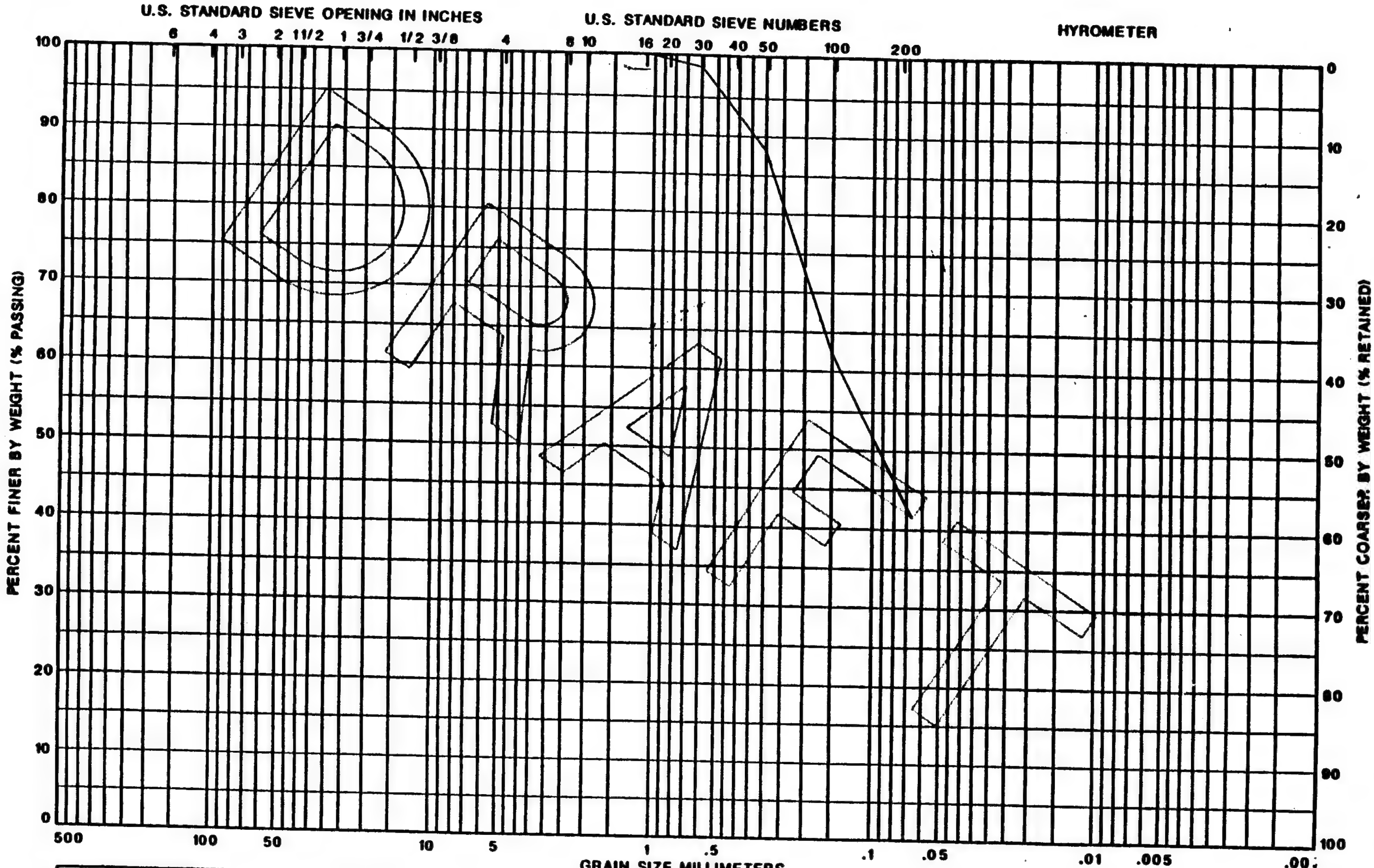


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
M-10002	8'	CL	SANDY LEAN CLAY	17.5	47	23	24

Woodward-Clyde Consultants

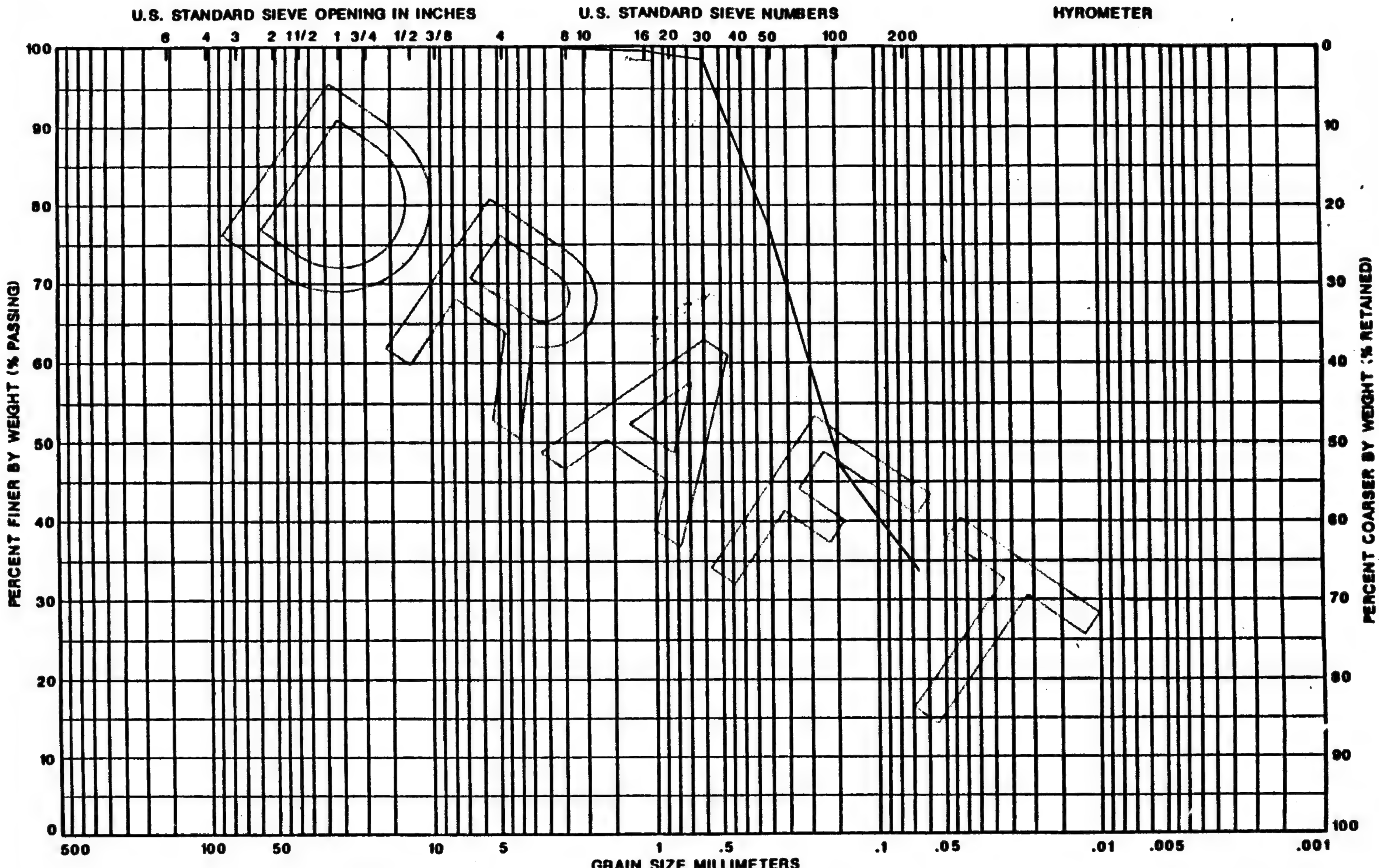
89MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
10003	2.5'	SC	CLAYEY SAND		28	15	13

Woodward-Clyde Consultants

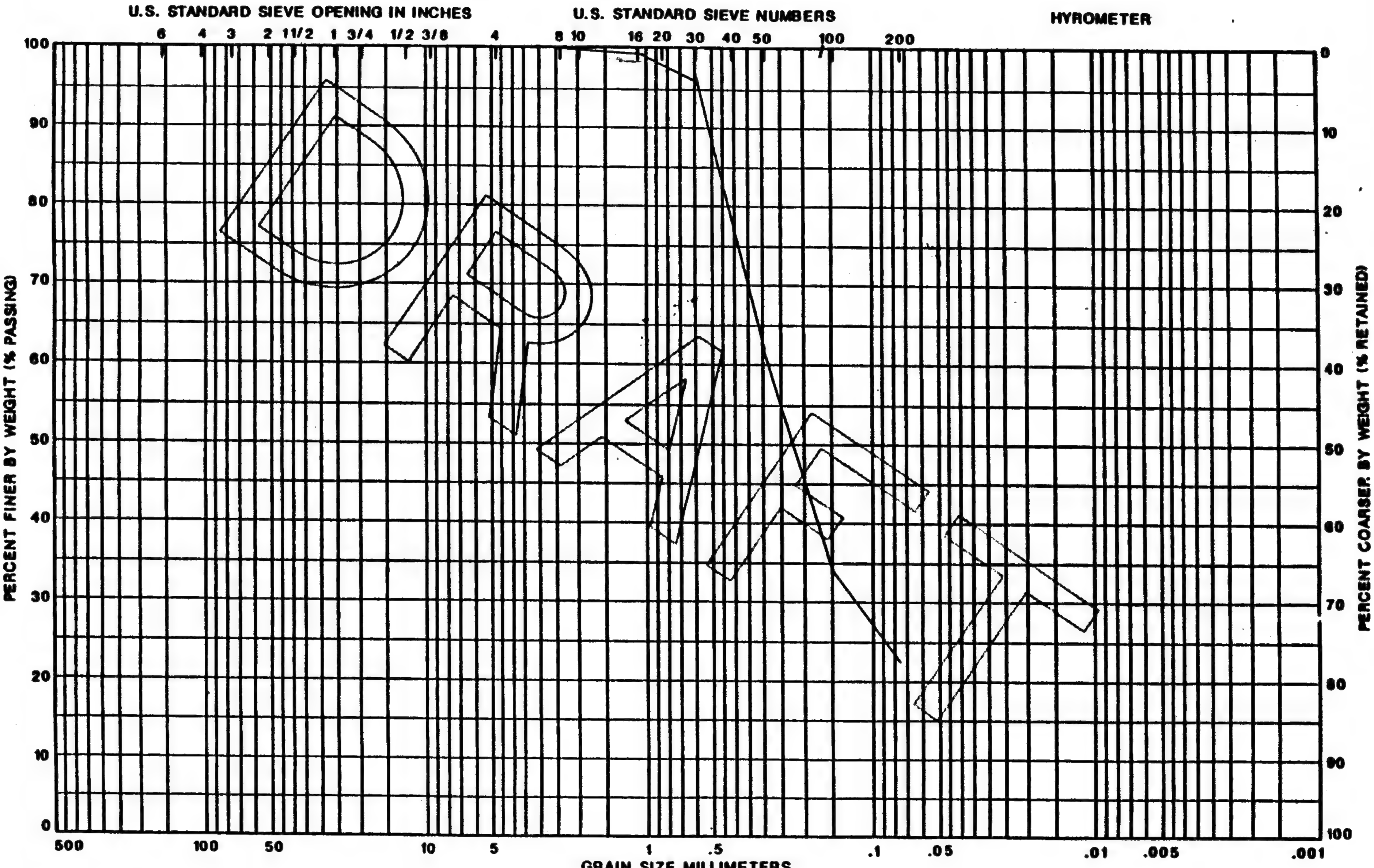


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
M-10004	5'	SC	CLAYEY SAND	4.7	26	11	15

Woodward-Clyde Consultants

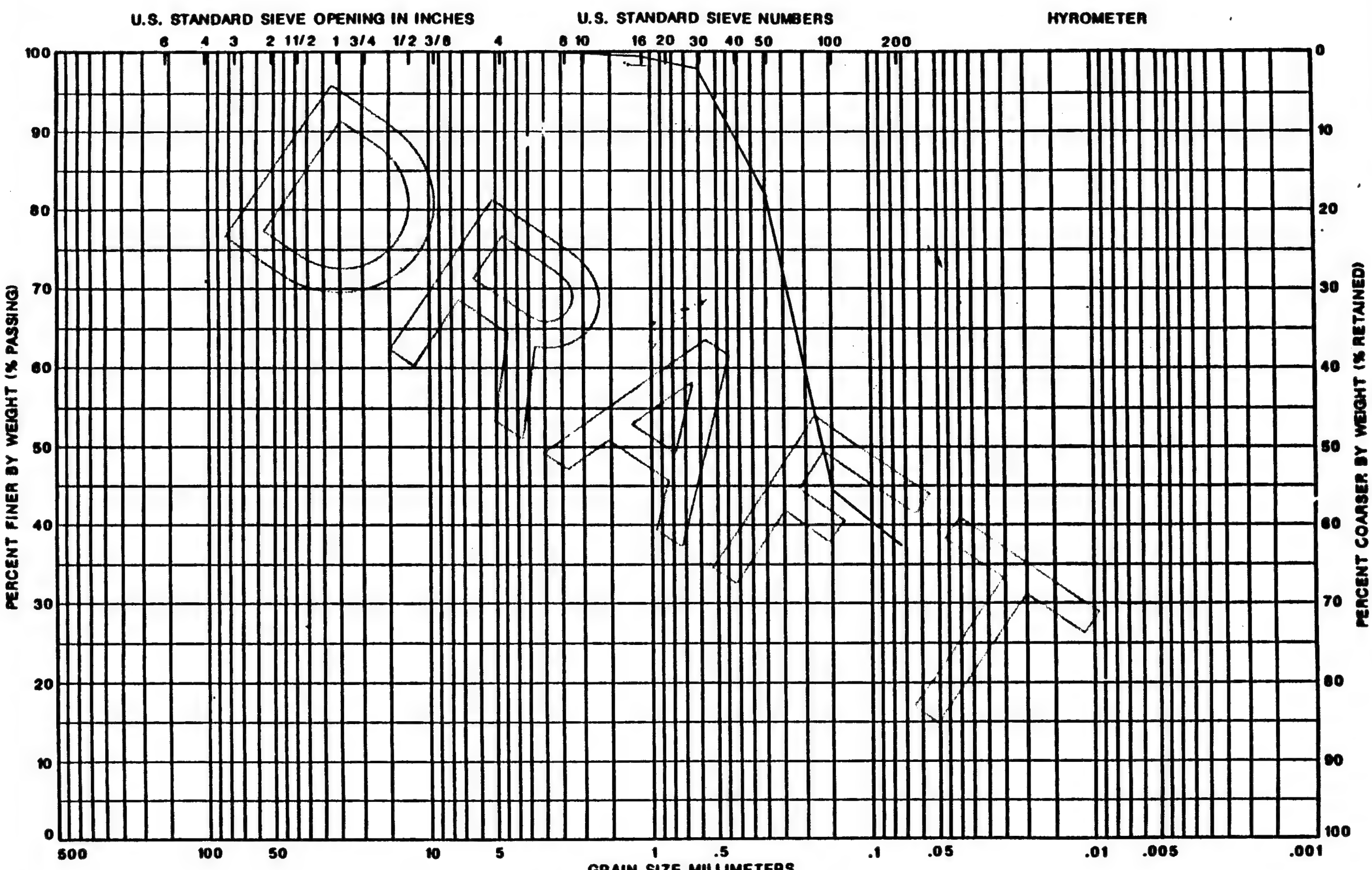
89MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
10005	7.5'	SC-SM	SILTY, CLAYEY SAND	3	26	20	6

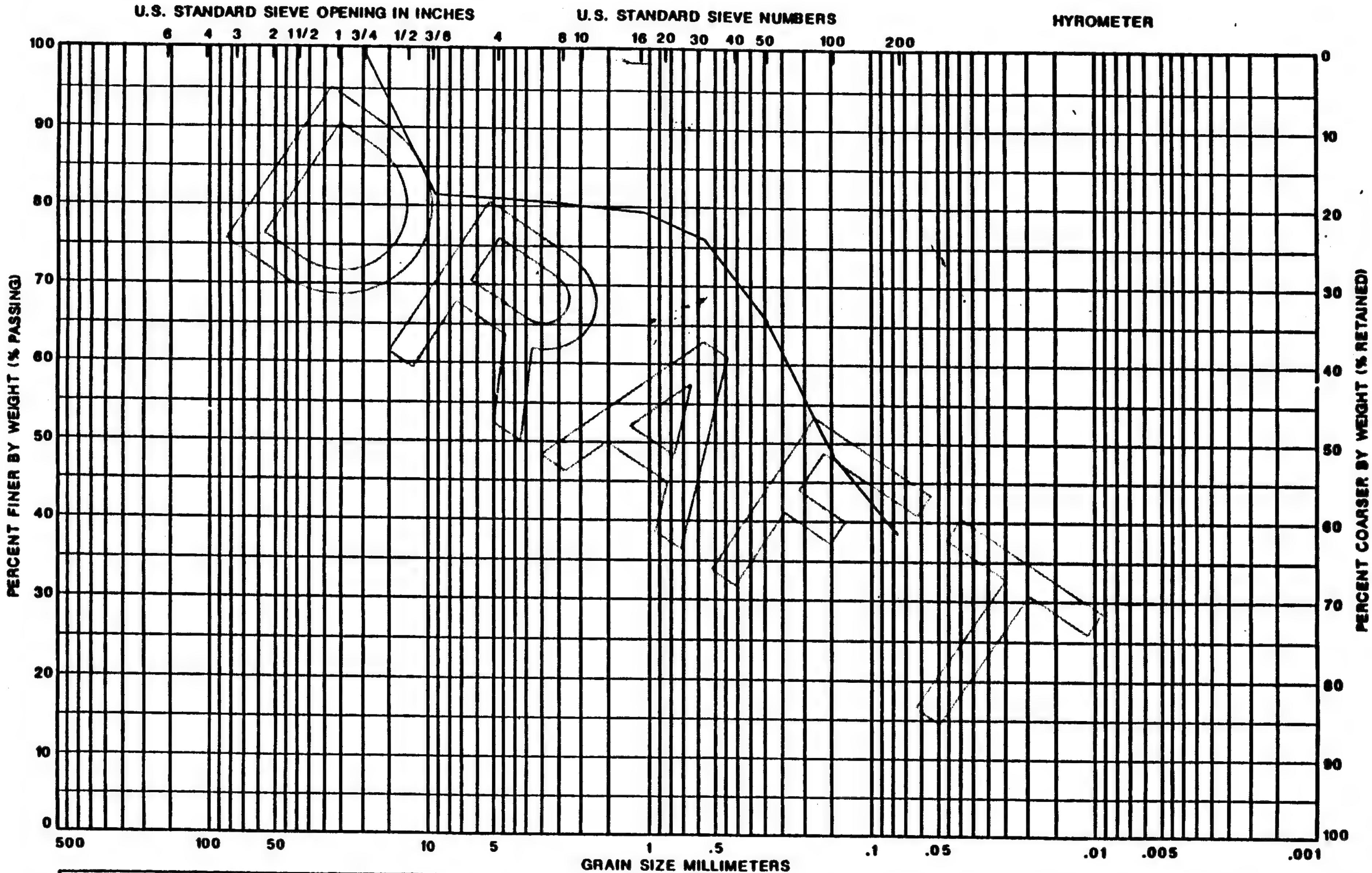
Woodward-Clyde Consult



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
M-10008	7.5'	SC	CLAYEY SAND	20.1	46	13	33

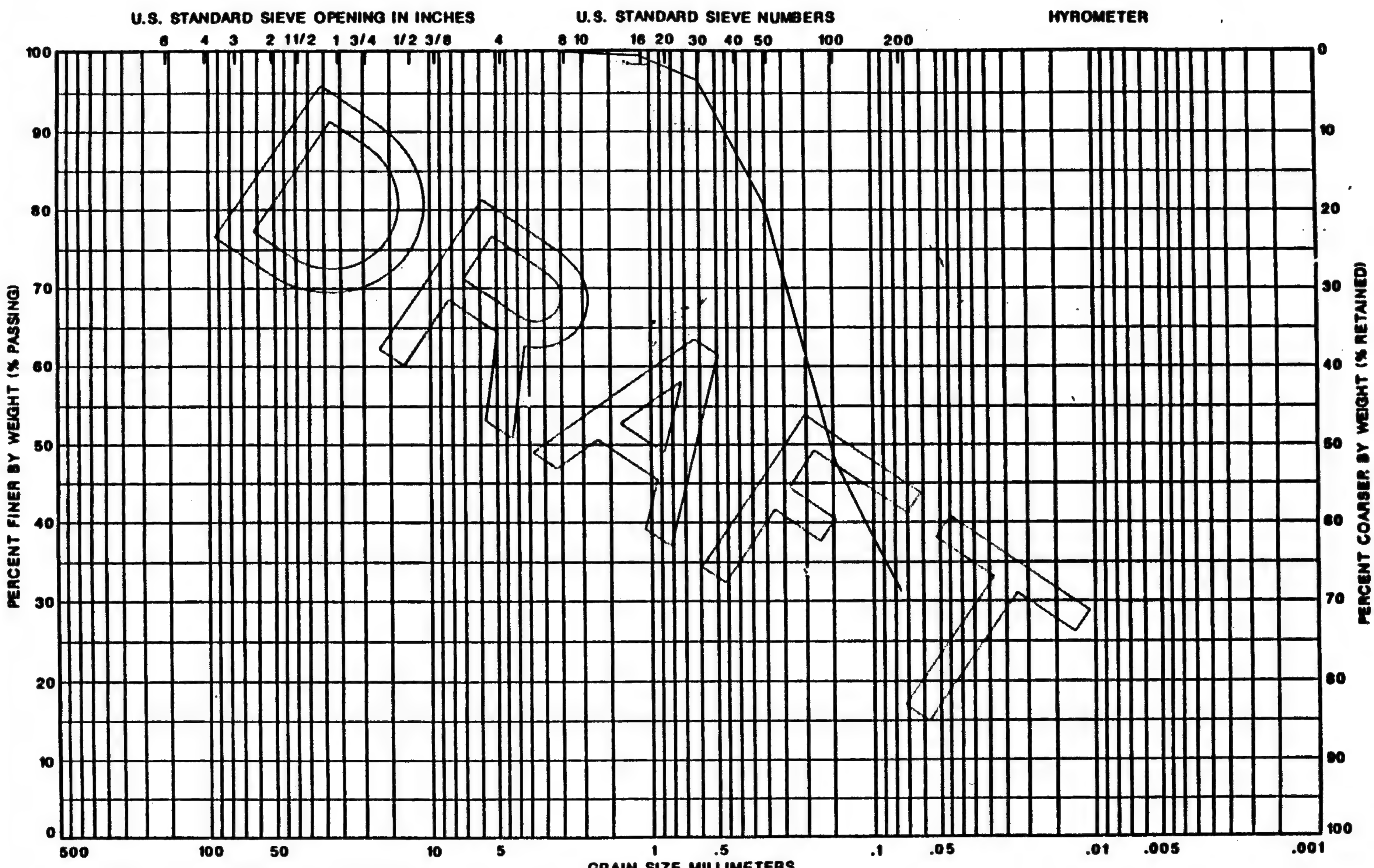
Woodward-Clyde Consultants



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
10010	10'	SC	CLAYEY SAND WITH GRAVEL	8	47	23	24

Woodward-Clyde Consultants

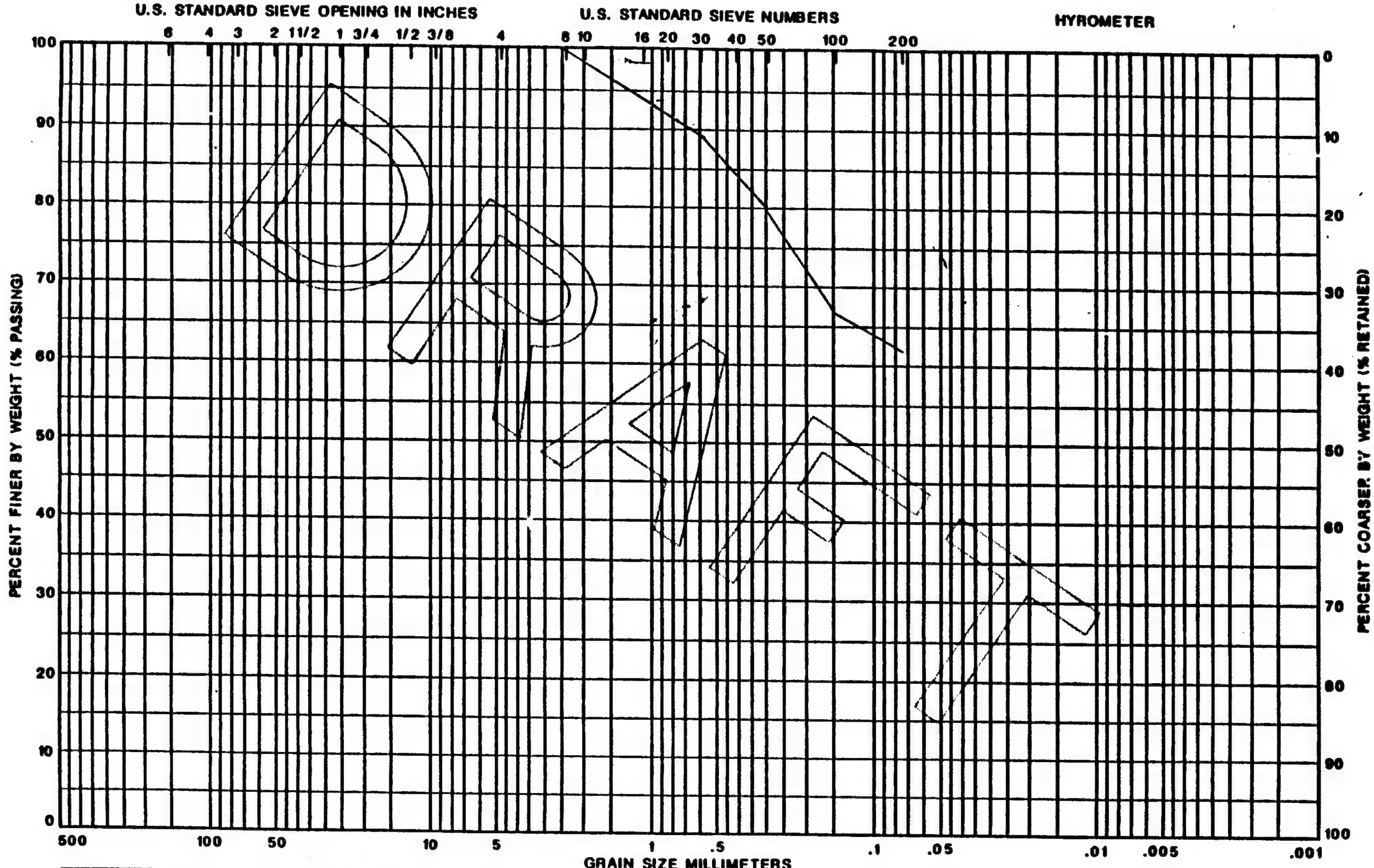


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
M-10022	2.5'	SM	SILTY SAND	10.1	N.P.	N.P.	N.P.

Woodward-Clyde Consultants

80MC114A



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	SYM.	CLASSIFICATION	NAT W	LL	PL	PI
M-10026	5'	ML	SANDY SILT	10.5	NP	NP	NP

Woodward-Clyde Consultants

REFERENCES

Environmental Science Engineering, Inc., 1987, Contamination Assessment Report Lime Settling Basins, Rocky Mountain Arsenal, Vols I and II.

Freeze, R. Allen and John A. Cherry, 1979, Groundwater, Prentice-Hall, Inc. New Jersey, 604 pp.

May, James H., 1982, Regional Groundwater Study of Rocky Mountain Arsenal, Denver, Colorado, U.S. Army Engineer Waterways Equipment Station, Vicksburg, Miss., Report 1 of a Series.

Stollar, R.L. and Assoc., 1989, Comprehensive Monitoring Program, Annual Ground Water Report for 1988, Vols I and II, Rocky Mountain Arsenal, Commerce City, Colorado.

U.S. Army Corps of Engineers, EM 1110-2-1901 dated 30 Sep 86, Seepage Analysis and Control for Dams.

Woodward Clyde Consultants, 1989, Results of field and Laboratory Investigations Conducted for the Remediation of Other Contamination Sources, Interim Response Action, Rocky Mountain Arsenal, Vols I and II.

_____, 1989, Final Alternative Assessment of Interim Response Actions for Other Contamination Sources, Lime Settling Basins, Rocky Mountain Arsenal, Commerce City, Colorado.

_____, 1989, Final Alternative Assessment of Interim Response Actions for Other Contamination Sources, M-1 Settling Basins, Rocky Mountain Arsenal, Commerce City, Colorado.

_____, 1990, Final Decision Document for the Interim Response Action at the Lime Settling Basins, Rocky Mountain Arsenal, Commerce City, Colorado.

_____, 1990, Final Decision Document for the Interim Response Action at the M-1 Settling Basins, Rocky Mountain Arsenal, Commerce City, Colorado.

_____, 1990, Field Investigation, Lime and M-1 Settling Basins Slurry Walls, Rocky Mountain Arsenal, Commerce City, Colorado, Vols I and II.

APPENDIX B

WATER SUPPLY & WASTEWATER COLLECTION

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 1	OF 3
ITEM Cutoff Walls and Cap for Lime and M-1 Settling Basins - Lift Station Design		BY JLB	DATE 9/28/90
		CHKD. BY RAK	DATE 10-10-90

Collection Trench Drain to Pump Station

Assume : Trench Drain flow rate = 5 gpm

$5\,gpm \times 60\,\frac{min}{hr} \times 24\,hr/day = 7{,}200\,gal/day$

Size Lift Station

Trench Depth ≈ 24 ft.

∴ Minimum Depth of Lift Station = 24 ft

Check Volume ⇒ I.D. = 3 ft $\quad V = \pi(1.5)^2(1) \times 7.481\,gal/ft^3$

$V = 53\,gal/ft$ depth

depth of sump = 5 ft

Storage Vol. = 5 × 53 = 265 gallons

Use depth = 33 ft. @ Diam. = 3 ft.

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 2	OF 3
ITEM Cut off Walls and Cap for Lime and M-1 Settling Basins - Lift Station Design		BY JLB	DATE 9/28/90
		CHKD. BY RAK	DATE 10-10-90

Sizing of Force Main and Pump

Length = 1000 ft

Friction $H_L = S \times L$ $S = \left(\frac{3.5519\,Q}{C\,D^{2.63}}\right)^{1.852}$ Hazen-Williams Q=gpm

C=120

D=diam. in.

S=Slope ft/ft.

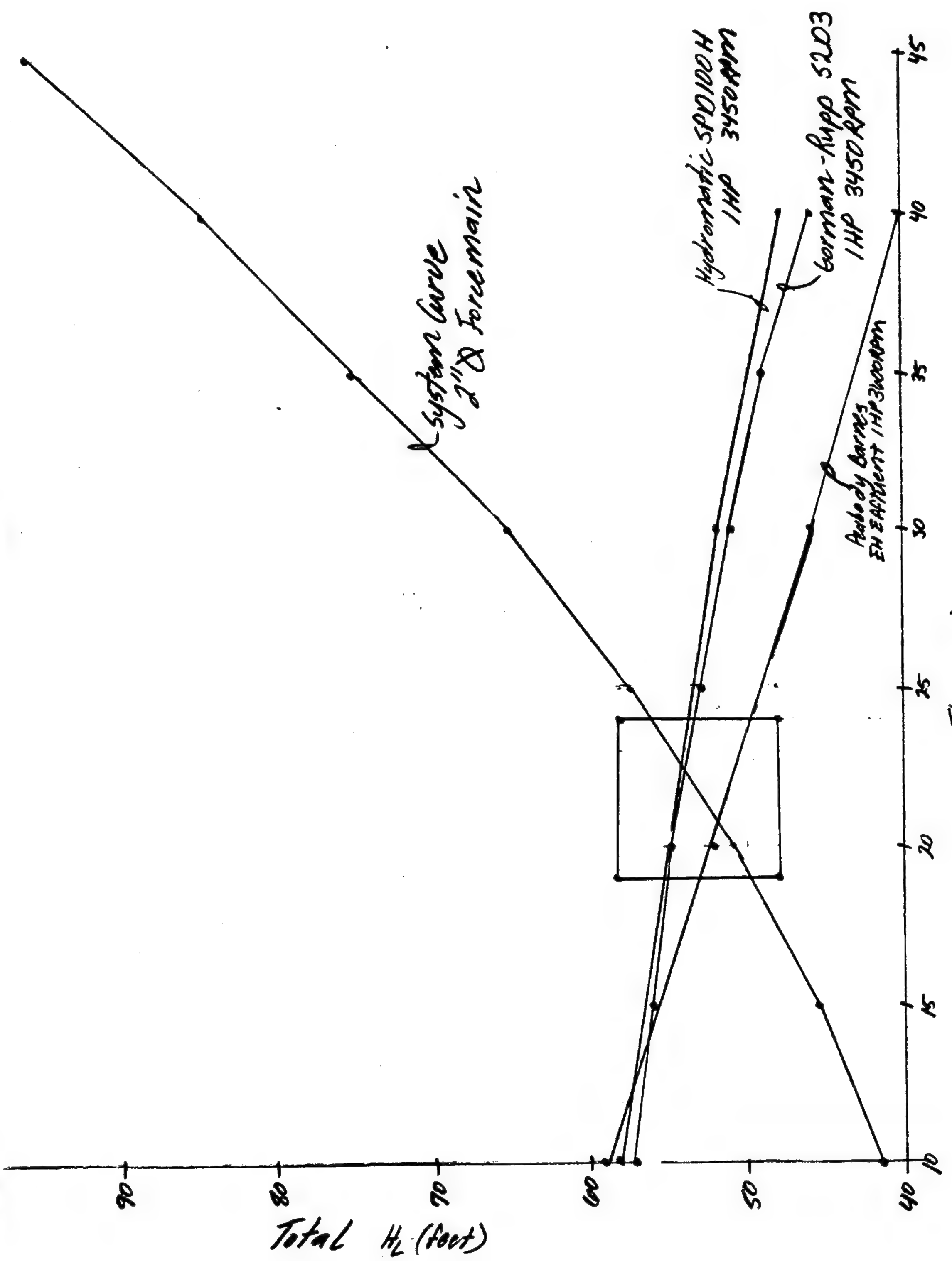
Static Head = CERCLA Floor EL - Lift Station Floor

5260 - 5222 = 38 ft.

Q	Friction H_L (ft) 2"	Static H (ft)	Total Head (ft)
10	3.6	38	41.6
15	7.6	38	45.6
20	12.9	38	50.9
25	19.6	38	57.6
30	27.4	38	65.4
35	36.5	38	74.5
40	46.7	38	84.7
45	58.1	38	96.1

MRO Form 1550, 1 DEC 83

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT		SHEET NO. 3	OF 3
ITEM Cutoff Walls and Cap for Lime and M-1 Settling Basins - Lift Station Design		BY JLB	DATE 9/28/90
		CHKD. BY RAK	DATE 10-10-90



APPENDIX C

ELECTRICAL COLLECTIONS

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Rocky Mountain Arsenal Lime Basin		SHEET NO. 1	OF 1
ITEM Voltage Drop for pump		BY RTL	DATE Oct 1990
		CHKD. BY LDD	DATE OCT 1990

Distance 100 feet
Load 2Hp motor 1ϕ, 240V, 12A

Amp-feet = 12A x 100 ft = 1200 A-ft

using table 5-7-1 in Buss Bulletin SPD81
Electrical Protection Handbook

for #10 AWG copper in plastic conduit
80% power factor 1ϕ from table 1978

Volt drop multiply A-ft x table and move decimal point 6 places

$V_{drop} = 1200 \times 1978 = 2.373600 = 2.4$ Volts

2.4 volts/240 volts = 0.01 = 1% drop

1% is less than 5% maximum and is acceptable.

use #10 AWG copper for 2HP motor

APPENDIX D

LIST OF PROSPECTIVE GUIDE SPECIFICATIONS

LIST OF PROSPECTIVE GUIDE SPECS

TABLE OF CONTENTS